REPORT 49A

SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

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TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

LAND RESHAPING OF LOWLAND CLAY SOILS

I. FIELD STUDY

FINAL REPORT

May, 1992

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EXECUTIVE SUMMARY

Land planing is a procedure to alter the field topography, producing a uniform slope thus improving surface drainage. Using laser technology for elevation mapping, in conjunction with computer software programs, a design plan is created outlining topsoil cut and fill depths and locations. An earth scraper with a cutting bar controlled by a laser elevation beam is then pulled across the field to produce the desired design.

Water management techniques such as the innovative approach with land planning however, must be closely examined to determine the sediment and phosphorus losses associated with the surface runoff. In the fall of 1988 Can-Ag Enterprises was awarded a contract to design and construct monitoring stations, then record and sample runoff at these stations.

The goal of this study is to determine the efficacy, costs and farm management changes associated with land reshaping, in comparison to conventional water management practices.

The study involved four farms, located in Essex and Kent counties, each with a planed and an unplaned field. Sites 2, 3, and 4 had a monitoring station at the primary surface outflow location on each field. The fields at site 1 were divided into sections, each section having a drainage furrow leading to a rock chute and therefore enabling three monitoring stations to be established on each field. The stations consisted of a V-notch weir, a stillwell with a Richards type flow meter, and later Isco automated samplers (two placed at sites 1 , 2 and 3). Throughout the study, runoff volumes were logged, samples were collected, soils were evaluated and agronomic practices and responses were recorded. Analysis for total phosphorus and dissolved molybdate reactive phosphorus were performed in the Land Resource Science Department at the University of Guelph. The sediment content was determined at the Harrow Research Station where the samples were filtered before being sent to Guelph.

Results of the soil investigations indicated a lack of impact, with regard to soil quality, from planing. At all sites, topsoils were not completely removed in any locations though in a few places there was evidence of topsoil

removal or addition. The assigned soil compaction ratings were similar for both the planed and unplaned field.

The results of the flow data indicated that increased runoff (L/ha) was associated with the planed field at two of the three well documented sites. Only at one site though, was the increased runoff (L/ha) on the planed field significantly greater than the unplaned field. Contrasting results were found at another site where the unplaned field contributed more runoff (L/ha) than the planed field. The fourth site had too few recorded events to be statistically analyzed.

The contrasting results between sites may be attributed to differences in the natural drainage patterns and differences in the sizes of the drainage basins. In the first year at site 2 though, we were able to construct basins of equal area on the planed and unplaned field using tomato beds. All the event occurrences with the equal area basins produced far more runoff (L/ha) from the planed field compared to the unplaned field. However there could be situations, such as at site 1, where dividing up the natural basins into smaller sections through planing would reduce the overall runoff.

The erosion characteristics of the two water management systems with regard to phosphorus and sediment losses through surface runoff are still not clearly defined. No consistent trends were observed or statistically determined, which might indicate that the phosphorus and sediment contributions to the runoff are event specific.

Differences between planed and unplaned fields appear when the sediment and phosphorus loadings are calculated with regard to total flow volumes. Sediment and phosphorus losses increased as runoff volumes increased. The planed fields on two out of the three well documented sites produced more runoff and therefore may contribute more phosphorus and sediment to the drainage channels. Obviously the key to reducing phosphorus and sediment loadings is to reduce runoff volumes. Determining the natural basins and drainage patterns within a field is the first step to choosing an

appropriate water management system. Creating smaller basins through planing may reduce overall runoff (L/ha) if the natural topography is prone to extensive surface runoff into adjacent waterways. However, the situation may be reversed if the natural depressions hold back the surface runoff. Eliminating these depressions through land planing will increase the surface runoff. Therefore in this circumstance farmers wishing to reduce field surface water should consider alternatives to land planing.

The interaction of total phosphorus, dissolved reactive phosphorus and sediment appear to be event specific, depending on rainfall intensity, soil conditions, antecedent moisture, ground cover, etc.

Differences in runoff and losses from the planed and unplaned field did not show up with respect to agronomic practices and the resultant residue cover. Combining the data from the planed and unplaned fields indicated that an established crop providing ground cover during the growing season significantly reduced the phosphorus and sediment loss to the surface runoff.

The costs of land planing are high, estimated between $260/ha and $790/hectare, yet increased yields (when compared to unplaned fields) may only be achieved in wet seasons. Other benefits reported by the farmers include: earlier spring start; elimination of hard spots (ponding areas); consistent crop growth; and harvesting at the opportune time. These benefits and the periodic yield advantages however, may only justify the initial costs of the land planing procedure when lucrative cash crops (i.e. tomatoes) are grown.

The modelling component of the study provides a prediction of whether or not a runoff event will occur but further modification to the model is necessary to produce accurate assessments of runoff volumes and phosphorus loss. As well further modification is needed to allow more agronomic input.

Several recommendations were made upon completion of the study. For fields already planed, these include:

- a reduction of drainage basin size (area with 1 outlet) to a range of two to five hectares (depending on field size).
- construction of proper grass waterways and outlet points to reduce field edge erosion and trap sediment runoff.

For farmers who have not planed but require water management techniques, we recommend:

- observe natural drainage patterns in the field
- consider costs and environmental impact of each system
- areas with high runoff volumes to adjacent waterways may experience a reduction in runoff if planed
- fields with isolated ponding areas will experience an increase in runoff if planed and therefore alternatives should be sought
- standpipe surface inlets and sediment traps are a cost effective alternative to the planing procedure.

For researchers, we recommend:

- small basin monitoring provides necessary data for field scale erosion research.
- control structures should be more permanent in nature and if economically feasible use data loggers to record flows.
- field scale monitoring should continue, to provide accurate model calibration data.

1. INTRODUCTION

Surface water ponding is an inherent problem of the lowland clay soils of Essex and Kent counties. A relatively new approach to water management on these flat agricultural lands is laser controlled land planing. Under the Technology Evaluation and Development (TED) research component of the Soil and Water Environmental Enhancement Program (SWEEP), innovative farming ideas such as laser planing are evaluated with respect to their effect on cropland runoff, phosphorus losses and productivity.

Can-Ag Enterprises was contracted by Supply and Services in the fall of 1988 to conduct a three year study on land planing, focusing on a comparison of runoff quantity and quality, soils and agronomic aspects of planed versus unplaned fields. Four cooperators allowed and assisted us to monitor, on each of the four farms, a planed and unplaned field worked under similar agronomic practices, as well as having reasonably controlled surface runoff outflows.

1.1 OBJECTIVES

The goal of this project was to determine the efficacy, costs and farm management changes associated with land reshaping, in comparison to conventional water management practices. The objectives of this research were:

1. to develop a method for measuring or estimating the differential phosphorus movement rates from cropped areas under the two different water management practices;
2. to locate suitable sites for the testing of these water management practices;
3. to monitor the P movement, crop yields and management requirements of the fields under the two systems; and
4. to analyze the data and report on the relative merits, associated difficulties and suggested improvements to water management by planing on lowland clay soils.

1.2 LITERATURE REVIEW

Land planing or grading has been a potential method of surface drainage on flat land since the early 1940's. It is defined by Sewell (1970) as "the practice of changing the topography of a field by making cuts and fills according to a predetermined plan to improve surface drainage." The introduction, in the last decade, of laser technology has added greater accuracy to this procedure. The laser provides a beam to control the depth of cut by the earth scraper as well as accurate filling of the depressional areas (Figures 1 and 2). The end result is a more precise surface slope permitting uniform runoff over the field. Because of improved surface drainage, there is potential for crops to be planted earlier, mature more uniformly, and be harvested at the most opportune time. Yield losses due to crop flooding are reduced, in the event of wet weather.

Edwardson et al. (1988) have stated that laser-controlled land grading may increase the efficiency and dependability of agricultural production. This increase in efficiency can result in lower production costs and greater profits. Increased dependability reduces the year-to-year variation in yields for the farmer and thereby provides a more stable income.

Land planing is relatively expensive and therefore the farmer must balance the construction and maintenance costs versus improved yields when determining the economic feasibility of planing. Results from Sewell (1970) in Tennessee showed no significant effects on corn silage yields over a three year period. But graded fields could be planted 9 days earlier due to improved surface drainage. The graded fields had practically no crop loss due to local wet areas and crop maturity was more uniform on the graded fields.

Edwardson et al. (1988) compared a graded (70 acres) and non-graded field (100 acres) in North Dakota where they observed greater yield variability (soybeans) and an annual average of 10 acres lost due to poor surface drainage on the non-graded field. Therefore an increased income could be expected due to more acres in production.

Figure 1. Laser Planing in Progress.

Figure 2. Laser Planing in Progress.

These economic evaluations of land planing have not taken into account any environmental implications associated with the practice of land planing. One of the objectives of this study was to analyze the data, including sediment and phosphorus losses, to report on the environmental performance of planed versus unplaned fields.

Phosphorus is considered to be the major cause of eutrophication within lakes and therefore much attention has been focused on methods to control this nutrient from entering the water system. The five year SWEEP program was introduced to reduce phosphorus loadings in the Lake Erie Basin from cropland runoff and to improve the productivity of agriculture by reducing soil erosion.

Only a certain portion of the total P load is actually capable of being utilized in biological growth. Dissolved inorganic P is considered to be the most bioavailable P form. Sediment P represents a major reservoir of P to algae; however, the availability of sediment P is uncertain. Sonzogni et al. (1982) defined potentially bioavailable inorganic P as the amount of inorganic P a P deficient algal population can utilize over a period of 48 hours or longer. Potentially bioavailable inorganic P thus corresponds to the dissolved reactive or molybdate reactive P (DRP or DMRP) plus the fraction of particulate nonapatite inorganic P (NAIP) obtained by extraction with O.1M NaOH (soil/solution ratio 1:1000) or by a comparable method.

Several studies, including Baker (1985), have shown that about 80% of the total P entering Lake Erie is particulate P; 20% is soluble P. Only about 25% of the particulate P is bioavailable and is subject to deposition in lake sediments while 90% of the soluble P is bioavailable. This is important to understand when reviewing control practices. Evidence indicates that some cropland runoff controls may effectively decrease total P loads but may not decrease, or even increase, soluble P losses (Baker 1982; Mueller et al. 1984).

Therefore, observing the performance of planed versus unplaned fields required emphasis on both sediment and nutrient runoff behaviour. Figure 3 from Storm et al. (1988) provides a visual explanation of the

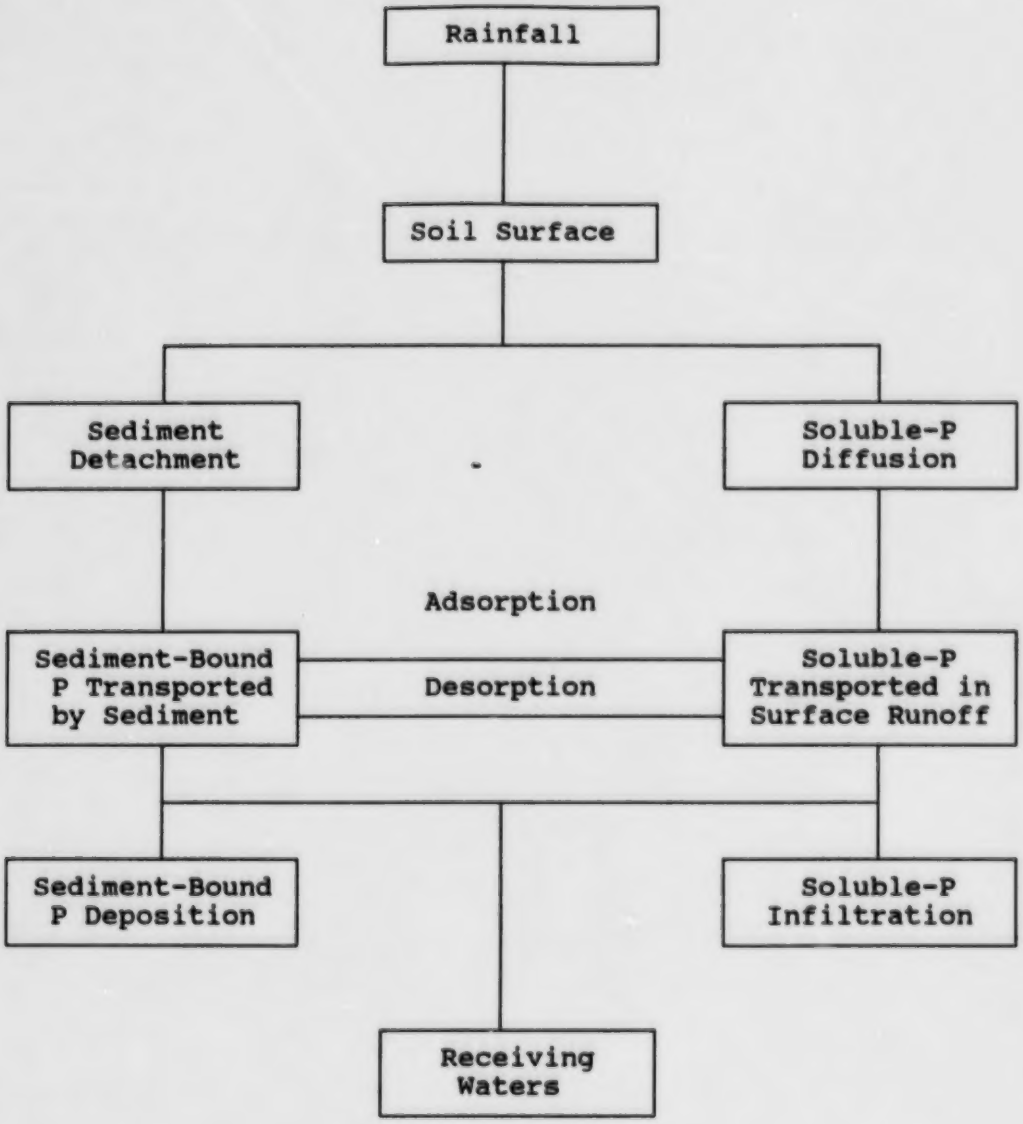

Figure 3. Phosphorus Transport Model (Storm et al., 1988).

phosphorus transport model. The desorption of soil phosphorus by rainfall and runoff is brought about by a turbulent mixing of surface soil with water caused by the impact of raindrops and the flow of runoff water (Ahuja et al. 1982)

When monitoring the field runoff for Total P, DRP and sediment it is important to examine the losses throughout the storm to determine if there are different results at different stages of the storm. Wendt and Corey (1980) conducted studies on loamy soils in Wisconsin where they collected runoff water at the start of the runoff at 30 minutes and at 60 minutes during a one hour simulated rainfall event. Their results show that there is an initial flush of nutrients at the start of the runoff (Table 1). However their results also indicate that the high level in the initial runoff is not maintained for a sufficient time to contribute markedly to the P loss. Plots from the study conducted by Wendt and Corey (1980) were on fine-loamy well drained soil developed on glacial till with an average slope of 5.1%.

Most of the research sites mentioned in the runoff studies differ substantially from the poorly drained lacustrine soil, a Brookston clay loam, with a slope less than 0.1% found at our study sites. Ahuja et al. (1982) results showed that the concentration of solution P in runoff water is appreciably influenced by slope length, degree of slope, soil cover and storm size. The degree of slope and soil cover primarily influence the effective soil mass that interacts with raindrop impact and runoff waters (increased solution P from increased slope and decreased soil cover). The slope length influences both the soil mass and water/soil ratio, and thus the kinetics of P release, by determining the overland flow depths and velocities along the slope (increase in slope length increased the average solution P per unit area of soil). The effect of storm size on average P concentration is a result of the kinetics of P desorption (increase in storm size increases P in solution).

Results such as these might suggest that flat agricultural areas are not a concern in the attempt to reduce P loadings but findings by McDowell et

Table 1. Variation in the Concentration of Sediment and of Several P Forms in Runoff With Time for Several Representative Events.* (Wendt and Corey, 1980).

Land use	Time of year	Minutes after runoff started: 0	30	60	Total runoff
			Total P, µ/ml		
Alfalfa	Apr	0.4	0.1	0.1	0.1
Alfalfa	Jul	0.5	0.2	0.2	0.2
Seedbed	Apr	3.2	1.9	1.8	1.8
Corn	Jul	3.2	1.6	1.3	1.1
Corn	Oct	2.6	1.5	1.4	1.2
			DMRP, µ/ml		
Alfalfa	Apr	0.05	0.04	0.02	0.03
Alfalfa	Jul	0.11	0.06	0.05	0.05
Seedbed	Apr	0.05	0.05	0.04	0.04
Corn	Jul	0.09	0.05	0.04	0.07
Corn	Oct	0.18	0.08	0.06	0.08
			Sediment, g/litre		
Alfalfa	Apr	tr**	tr	tr	tr
Alfalfa	Jul	tr	tr	tr	tr
Seedbed	Apr	3.3	1.8	1.6	1.4
Corn	Jul	3.8	1.9	1.5	1.3
Corn	Oct	3.9	2.3	1.2	1.4

* Data are the average of two or more high-intensity events except for the seedbed for which data from a single event are presented.

** tr, trace.

al. (1984) from a flat Mississippi delta watershed showed much greater amounts of sediment and nutrients in the runoff than expected. Their research results found that only 7% of the total P was transported in solution, the remainder was transported by the sediments. They also concluded that reducing the soluble P concentrations in runoff would be difficult because soluble P concentrations were unrelated to runoff volumes and sediment concentrations. Sediment P concentrations, in mg/L were linearly related to the sediment concentration in the flow.

Studies in flatland areas have revealed higher than expected amounts of sediment and total P concentrations in the runoff. Our study under the SWEEP-TED program has attempted to determine if planing the fields alters quantity and quality of the runoff when compared to the unplaned fields.

2. MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN

An experimental design evolved from inter-related and parallel activities: synthesis of existing knowledge; selection of appropriate sites; database design, modelling approaches; technical requirements; monitoring requirements; and project resources.

As part of this design, the following null hypotheses were identified:

1. Seasonal and annual run-off characteristics (timing, volumes, quality) are not affected by land planing. If rejected, identify optimal conditions for minimizing environmental impact in quantitative terms.
2. Various crops routinely grown by farmers will not respond differently to land planing. If rejected, identify optimal treatment for each crop in quantitative terms.
3. Various tillage practices implemented by farmers and resultant crop residues do not affect runoff characteristics differently on planed versus unplaned fields. If rejected, quantify the effect.
4. Soil conditions in planed fields do not change following planning. If rejected, describe the changes.
5. Spatial variation in run-off within a planed and unplaned field are similar. If rejected, quantify the effects.

The analytical as well as modelling approach are based on data collected from four farms each with a planed and unplaned field. All fields have tile drainage. Sites were chosen where surface runoff was limited to one or two outflow points. The exception to this was site 1 where six drainage areas were monitored (three on the planed, three on the unplaned) each with its own weir and flow recorder at a rock chute outlet. These four pairs of fields were then monitored to determine runoff volumes and phosphorus and sediment loss. Figures 4 to 7 are site location maps which also show the weir placement for each field.

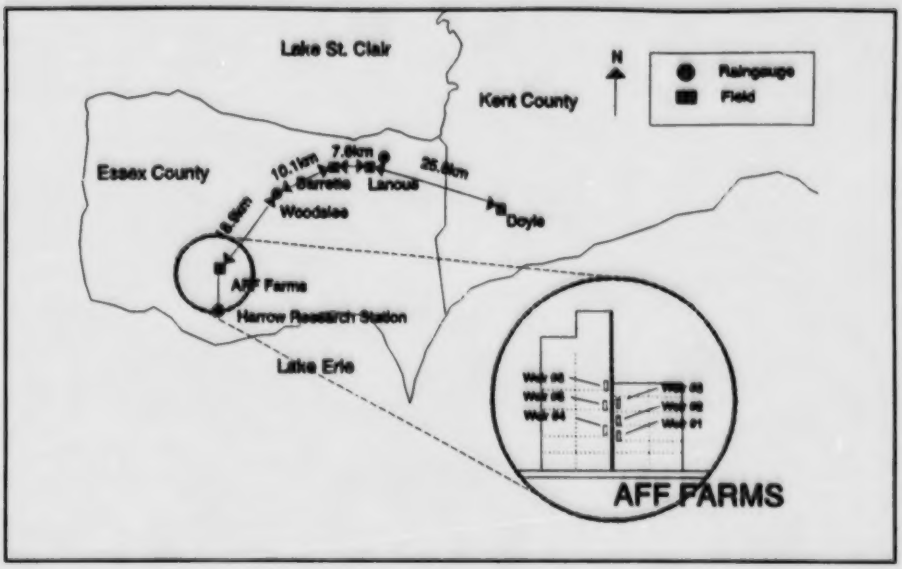

Figure 4. Site 1 Location Map.

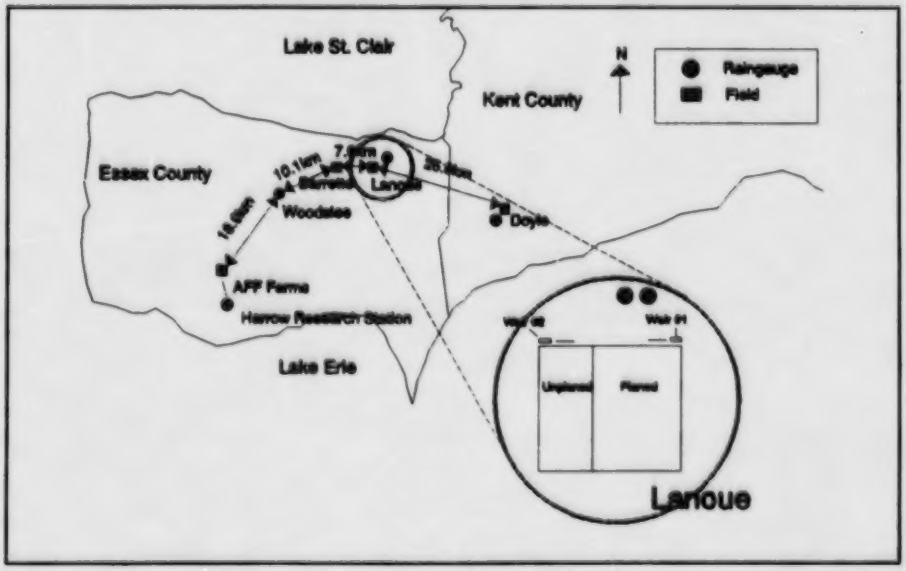

Figure 5. Site 2 Location Map.

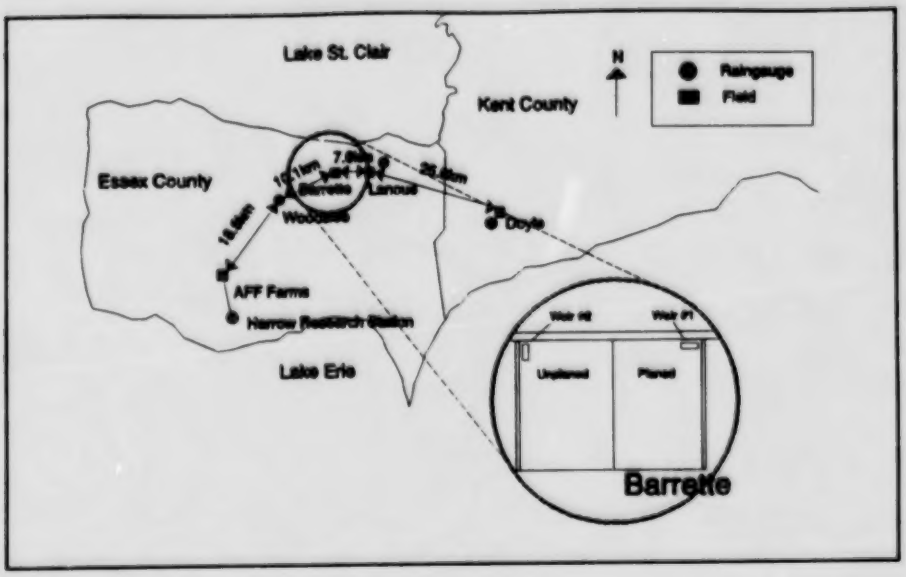

Figure 6. Site 3 Location Map.

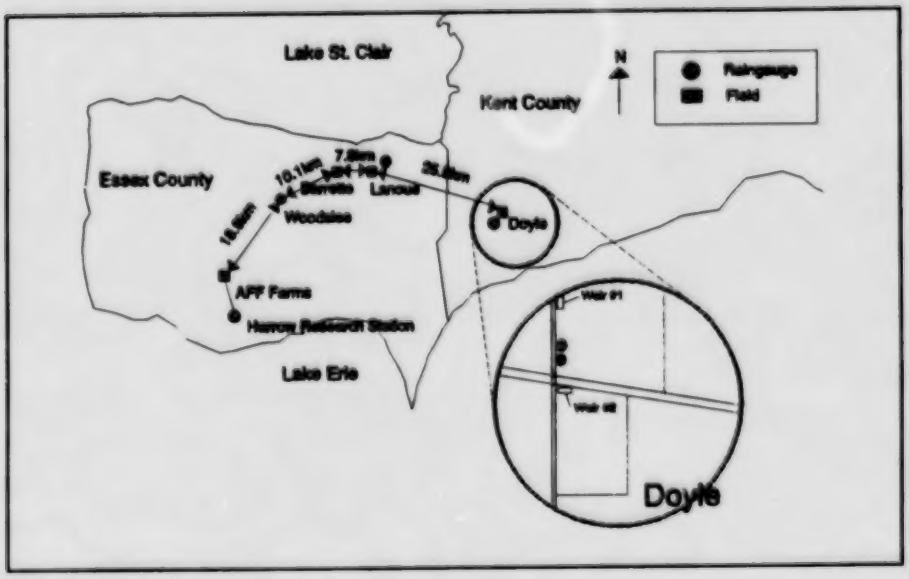

Figure 7. Site 4 Location Map.

The agronomic practices (tillage, fertilizer and herbicide inputs, etc.) were identical, when possible, for each field in the pair. The "when possible" refers to situations that can occur which cause the farmer to alter his particular plans. This is a common problem with field scale research but must be taken into account since the study did not offer any compensation for yield loss.

2.2 BASIN CHARACTERIZATION

Defining the drainage basin or micro-watersheds' size is extremely important in providing accurate estimates of runoff volumes and nutrient and sediment losses on a per hectare bases. Using the planing design map, a relatively precise picture of post planing elevations in the field can be determined, as long as the farmer closely followed the planing plan. The unplaned fields were also laser surveyed to provide the natural elevations in the fields. Contour maps were produced for all fields but these could not define the micro-watersheds in each field. Additional maps were produced by Mr. R. MacMillan from the Alberta Research Council who is employing micro-watershed modelling software for his Ph.D. research. These maps were further transformed into three dimensional maps distinguishing individual basins within a field and the corresponding natural drainage network.

2.3 MONITORING STATIONS

Flow measurements and samples were collected from monitoring stations which were situated at specific outflow points. Custom made plywood V-notch weirs were installed at outlets of grassed waterways, rock chutes or plowed surface drainage furrows. Each station was equipped with a Richard's type water level recorder which measures water height via a float which travels vertically in a custom made stillwell. The stillwell was placed on the upstream side of the weir with the inlet at ground level. The recorder transfers the float movement to a calibrated measurement on the chart paper (Figure 8). Using

Figure 8. Monitoring Station

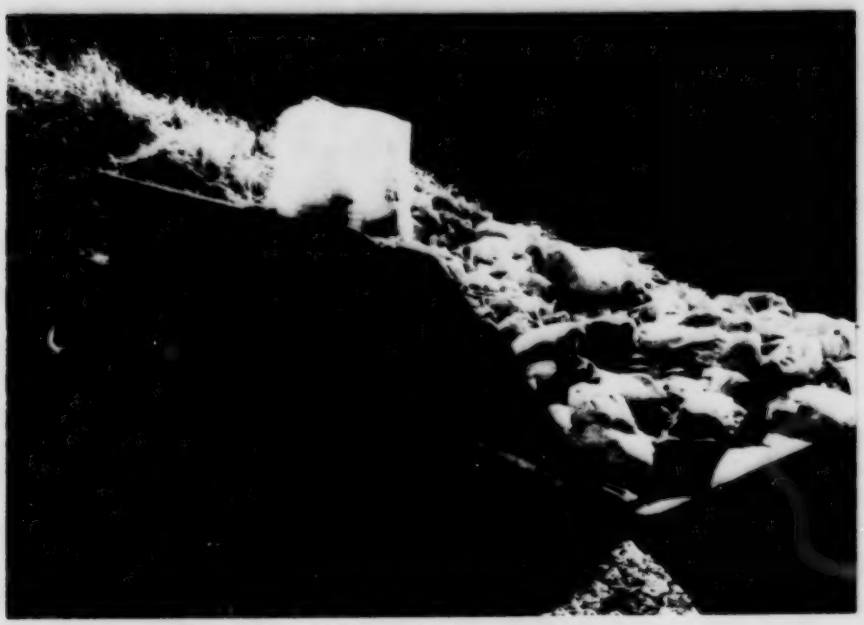

Figure 9. Isco Automated Sampler

standard formulas based on a 90° V-notch weir, the water heights were converted to a flow (L/s) measurement.

In March of 1990 six Isco automated samplers were installed at three sites (Figure 9). The Isco model 2900 that was implemented in the study is a portable device designed to collect up to 24 separate sequential samples (maximum 500 ml/sample). The sampler's programming capabilities allows the user to choose volume collected as well as the time interval between samples. The Isco sampling routine was initiated by runoff water contact with an actuator. The sampler actuator is a device used in conjunction with the Isco sampler to begin a sampling program when the liquid level reaches a predetermined height. The sampler inlet tube and actuator sensor pin were staked to the channel bottom just in front (upstream) of the weir. For this study, the Isco was programmed to collect a 250 ml sample every hour for a 24 hour period once it was activated. Even if the flow level dropped below the actuator sensor pin the Isco would continue to run for the 24 hour period. With this program, it could easily be determined from the flow charts when the Isco started its cycle.

2.4 LABORATORY ANALYSIS

Automated and manually collected samples were taken to the Harrow Research Station. A 50 ml aliquot was filtered through a 0.45 μm filter to determine sediment content as well as providing a filtered sample for analysis. The two containers for each sample, one for total P and the other for filtered reactive P, were then sent to Guelph. At the University (Land Resource Science Department), Andrew Marshall, a graduate modelling student, digested the unfiltered sample using the perchloric digestion method. The digested and filtered samples were then analyzed on the Technicon Autoanalyzer for total P and dissolved molybdate reactive P (DMRP) respectively.

The DMRP method is based on Murphy and Riley (1962) with modification by Dirk Tel, Instrument Scientist with the Land Resource Science Department, University of Guelph. It is recognized that some particles not truly

in solution may pass a 0.45 μm filter and therefore the DMRP analysis will be referred to as filtered reactive phosphorus (FRP) in this report. The total P method is from the American Public Health Association's standard methods for the examination of water and waste water.

The methods chosen for this project appear to be the best suited yet they differ slightly from Ministry of Environment procedures, Harrow Research Station methods and other labs doing SWEEP analysis. These minor modifications between procedures can create inconsistencies in P evaluation when comparing to other SWEEP projects. We would suggest that any future large scale programs dealing with the fate of nutrients or chemicals have a standard analysis method that would apply to all projects within that particular program.

2.5 FIELD INVESTIGATIONS

A baseline soil survey was conducted in the first year to gather pertinent soil characteristics of the test fields and examine variations within the fields. The survey provided a field scale view of the soil profile including: horizons; structure; texture; topsoil depth; compaction; etc. An intensive soil investigation was completed in micro watersheds within each field. Soil pits were dug and samples were taken to determine particle size, bulk density and organic matter content. Key visual observations were also recorded, specifically structure determination (using McKeague's rating system) with respect to compaction and earthworm counts. Composite samples of the topsoil were taken each fall for nutrient, organic matter and pH analysis.

Crop development was observed each growing season to identify problem areas within the fields. These regions of poor growth were then examined with greater detail to determine a possible cause (i.e. excessive moisture, shallow topsoil, compaction, etc.).

After the final fall operation was completed, the amount of surface residue was determined and an overall cropping management factor was

estimated. The cropping management factor (C-value) reflects the influence of various types of crop canopy and management practices on soil erosion by water. The C-value is the ratio of soil loss from a field with specific vegetation or cover and management to soil loss from the standard, bare or fallow condition (Wischmeier and Smith, 1978).

2.6 AGRONOMIC PRACTICES

Agronomic records were kept by the farmers to indicate dates and type of operations performed, fertilizer applied, fuel consumed, etc. These records indicated whether the planed and unplaned fields were both farmed with the same inputs and practices and if planing altered the timing of any operations. The crop yield was also determined by the cooperator using grain elevator scales. The yields in conjunction with the measured inputs and farmer estimations of planing costs provided some information with regards to land planing economics.

2.7 CLIMATIC RECORDS

Rain gauges (weighing bucket type) were set up at two sites in the spring of 1989 and at a third site in the late winter of 1991. On-site gauges were necessary due to the intense spatial variability associated with precipitation events in southwestern Ontario. The first two sites had two rain gauges at each location, one gauge providing daily chart recordings and the other, weekly recordings. The third site only had a weekly recording rain gauge. The farmers also kept climatic records referring to soil conditions (i.e. ponding, wet, moist, dry, cracked, frozen, snow, etc.) and significant climatic events (i.e. thunderstorm, flooding, hail, high winds, snow storm, snow melt etc.). Additional climatic data were obtained from the Harrow Research Station and the Woodslee Research Station to provide precipitation information in case of malfunction by our rain gauges. The research stations also provided daily temperature data as well as long term averages for temperature and precipitation.

2.8 MODELLING

The main computer modelling objective was to determine empirical values for field parameters. These parameters affect the estimations of surface and sub-surface drainage of agricultural lands across seasons in southwestern Ontario at field scale. The original workplan had stated that the goal of the modelling component was to obtain estimates of flow, sediment and P loading from planed and unplaned fields. However, the quantitative estimates for the field parameters were not readily at hand. Therefore, the parameters were determined which enabled the modelling of occurrences. During a surface drainage event phosphorus is transported by the water medium. Therefore, by accurately modelling overland drainage episodes, modelling of phosphorus transport could be enhanced.

Andrew Marshall, a graduate student in the Department of Engineering at the University of Guelph, determined the empirical values of field parameters (pertaining to our study location) in four related steps. These were: (1) comparison of available methods used in representing field parameters, (2) examination of field data, (3) modification of the CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) model to allow for changes in parameters by season, and (4) development of a procedure for determining the empirical values for field parameters.

The first three steps were prerequisite to the fourth step. Comparison of the available methods produced the optimal method for representing field parameters. Examination of field data provided information required to represent the field conditions. Modification of CREAMS enabled the model to represent better the field conditions as they varied with season. Method for determining the empirical values for field parameters could then be developed and completed. Table 2 lists the parameter groups and their associated sources.

Table 2. Parameter Groups and Associated Sources.

Parameter Group	Data Source	Parameter Name	Parameter Definition
Precipitation	Precipitation Gauges	PREC	Precipitation
Solar/Temperature	Agriculture Canada	TEMP	avg. monthly temp.
		RADI	avg. monthly radiation
Hydrologic	Field Surveys	DACRE	field area (acres)
		SLOPE	avg. field slope
		XLP	length of flow plane
Crop	Farmer's Records	LAI	leaf area index
		DP	depth of root zone
		RMN	roughness coefficient
		GR	winter cover factor (snow cover condition)
Soil	Soil Pits, Textural Analysis	RC	effective saturated conductivity
	and	GA	effective capillary tension
	Previous Research	POROS	soil porosity
		BST	portion of plant-available water storage filled at start
		DS	depth of surface soil
		BR15	immobile soil water content
		FUL	portion of plant-available water filled at field capacity
		CONA	soil evaporation parameter

2.9 DEVIATIONS FROM THE ORIGINAL WORKPLAN

Several alterations from the original workplan occurred throughout the course of the study. The monitoring schedule that was outlined in the original design stated that six events would be monitored each year, reflecting various climatic (i.e. runoff from frozen soil, spring melt, spring rains, summer thunderstorms etc.) and soil conditions (i.e. preplant, crop canopy, harvest, post tillage etc.). We soon realized that all runoff events should be monitored and sampled as events were sporadic and inconsistent between sites. The samples were originally hand collected as per the workplan. Later, simple but effective Can-Ag built samplers were added, followed by the Isco automated samplers. The Can-Ag built sampler collected two samples from two different stages of the event and, as previously mentioned, the Isco could collect a sample every hour up to a maximum of 24 samples. The automated samplers provided much more data (i.e. sediment, filtered molybdate reactive P and total P analysis) than would have been obtained through manual sample collection, as well as eliminating the dangers of collecting samples during a thunderstorm. The Harrow Research Station was the original site for the lab analysis, performed by a Can-Ag technician, but was changed to the University of Guelph so that Andrew Marshall could do the analysis.

In the fall of 1988, twelve sediment traps were installed at site 1 (six traps on the planed, six on the unplaned). Two major problems arose over the course of the winter. First, poor flow which resulted in ponding within the trap boundaries, and second, the heaving of collection drums. The traps failed to produce reliable data and were therefore removed in the spring and not used again.

The farmer at site 1 divided both his planed and unplaned fields into smaller drainage sections by creating drainage furrows that lead to rock chutes along the main ditch (which separated the two fields). This design produced distinct micro drainage basins that could be monitored separately. Therefore, six weirs were installed at site 1 instead of the originally planned two weirs. Thus, twelve monitoring stations were established (four more than the original design).

3. RESULTS

3.1 BASIN CHARACTERIZATION

The drainage basin maps provided an initial estimate of the percentage of each field that drained thorough the monitored weirs. This allowed the runoff information (volume of water, phosphorus and sediment) to be converted to a per hectare measurement.

Figures 10 to 25 show the topography and drainage areas for the monitored weirs at each field (the different patterns represent the drainage basins). With the uniform slope of the planed fields, drainage areas were primarily defined by the drainage channel boundaries. On the unplaned fields, we relied on the micro-watershed maps to determine boundaries. These boundaries are based on the natural field elevations but can easily be altered by the farmer, through tillage practices and the construction of drainage furrows (which may drain opposite to the general land slope). Figure 76 in the Appendix shows the drainage pattern for the unplaned field at site 1 if no surface drains were constructed in the field. Increasing the sensitivity in identifying the watersheds will increase the number of micro-watersheds as shown in Figures 77 and 78 in the Appendix (unplaned field at site 1). These figures indicate that defining the micro-watersheds can relate to the storm intensity. A minor event may only trigger drainage from a few of the micro-watersheds while a major event could trigger all the micro-watersheds. This obviously distorts the per hectare measurement when we use the same watershed area for all events. Therefore, providing a precise value of the drainage area for each event was beyond the scope of this project. However, we were able to estimate an area value for each weir, that was used throughout the course of the study. The exceptions to this occurred at two sites. In the first year a portion of the field, at site 2, was monitored with boundaries created by tomato beds and berms. After the tomato beds were worked up in the fall the entire field was then monitored. At site 1, in the final year, half the unplaned field was planed in the late summer of 1990.

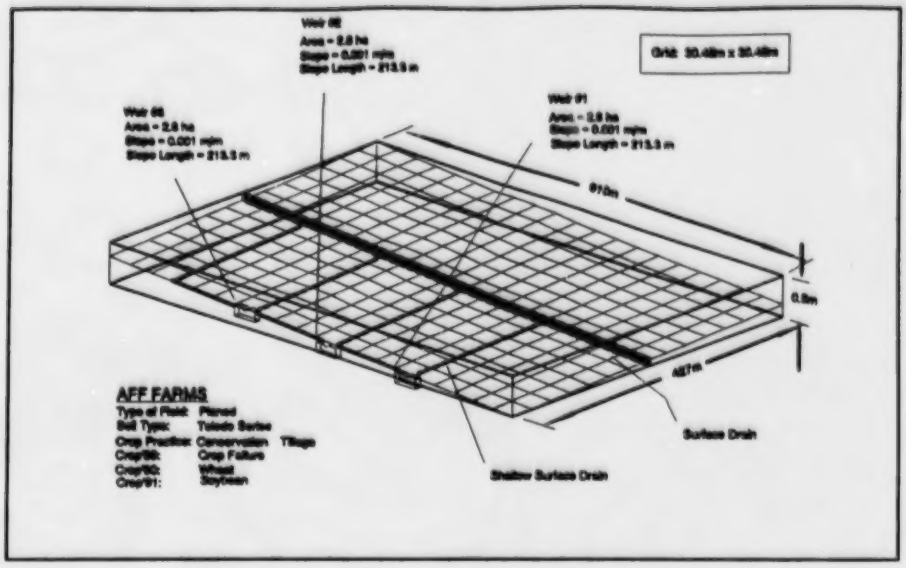

Figure 10. Site 1: Planed Field Topographic Map.

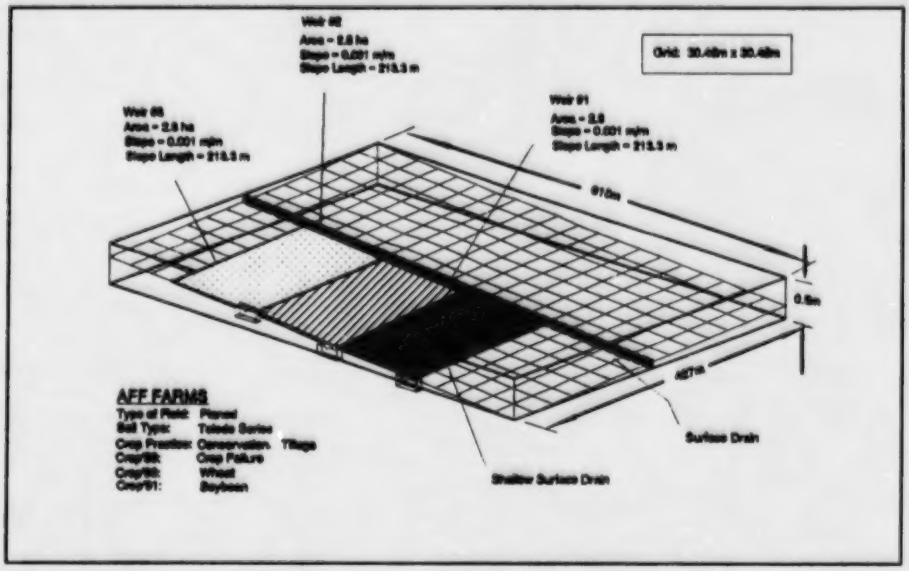

Figure 11. Site 1: Planed Field Drainage Basin Map.

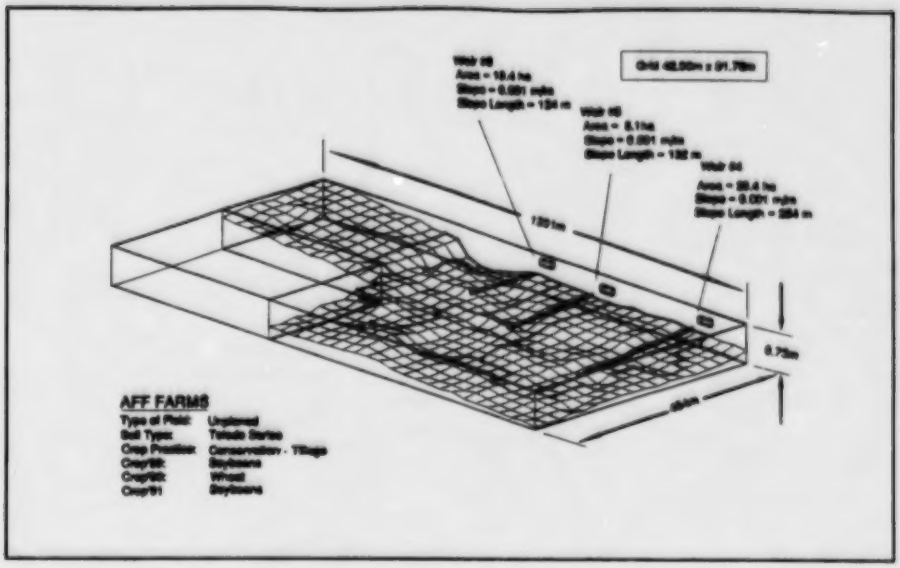

Figure 12. Site 1: Unplaned Field Topographic Map.

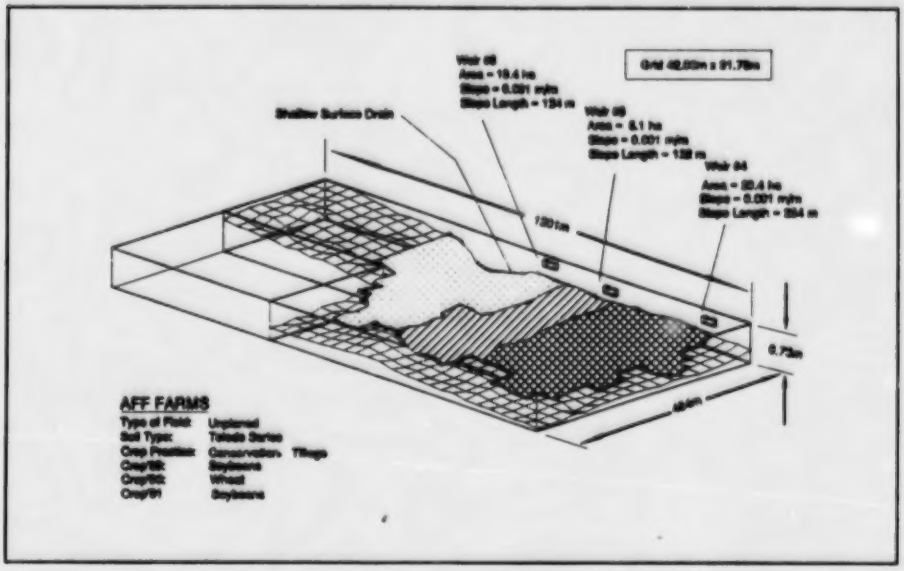

Figure 13. Site 1: Unplaned Field Drainage Basin Map.

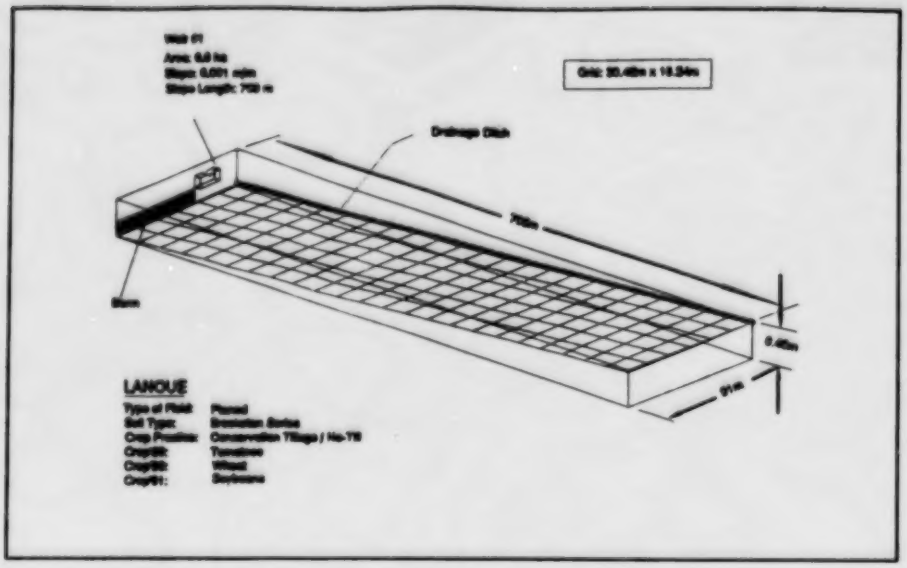

Figure 14. Site 2: Planed Field Topographic Map.

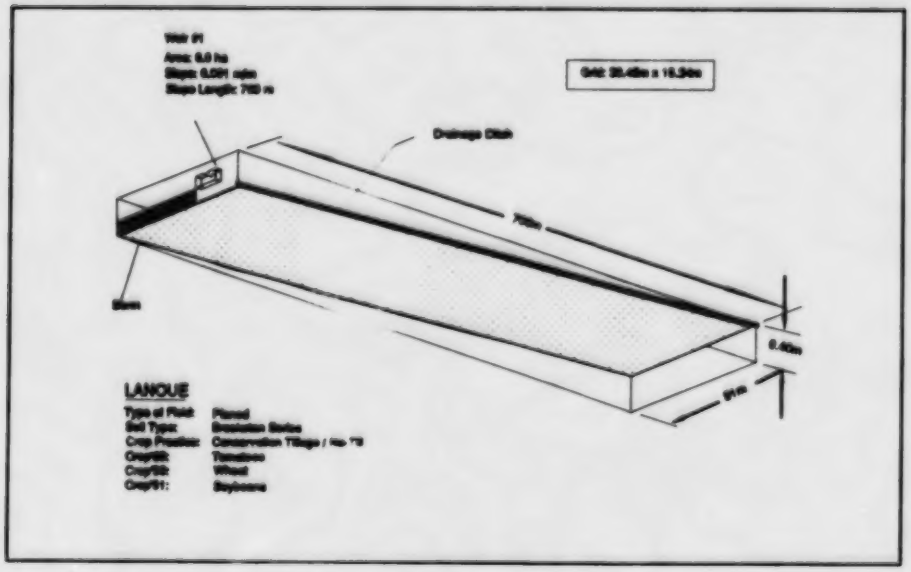

Figure 15 Site 2: Planed Field Drainage Basin Map.

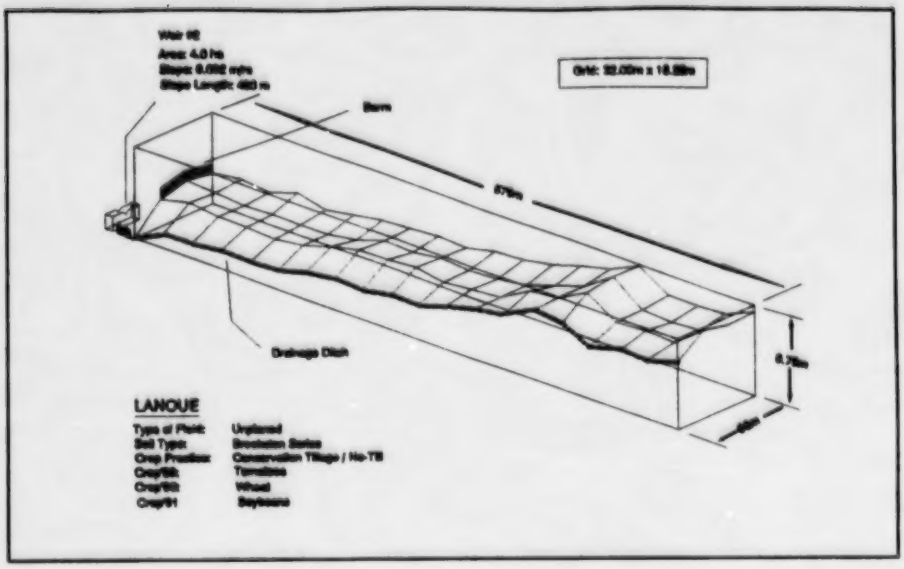

Figure 16. Site 2: Unplaned Field Topographic Map.

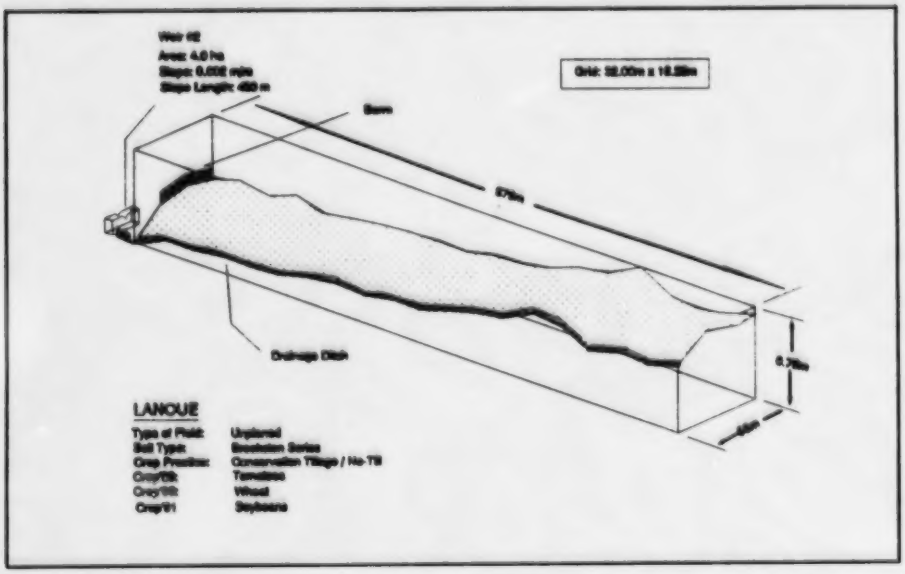

Figure 17. Site 2: Unplaned Field Drainage Basin Map.

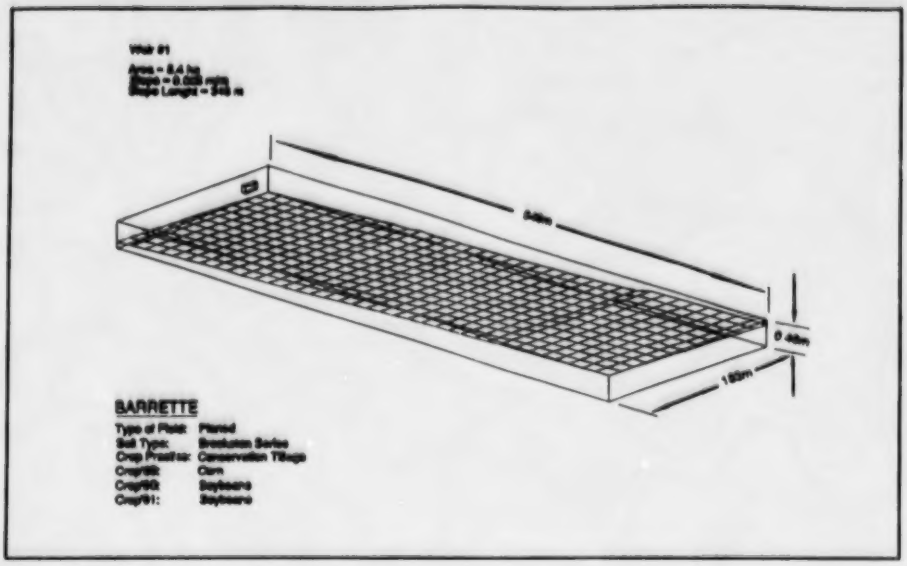

Figure 18. Site 3: Planed Field Topographic Map.

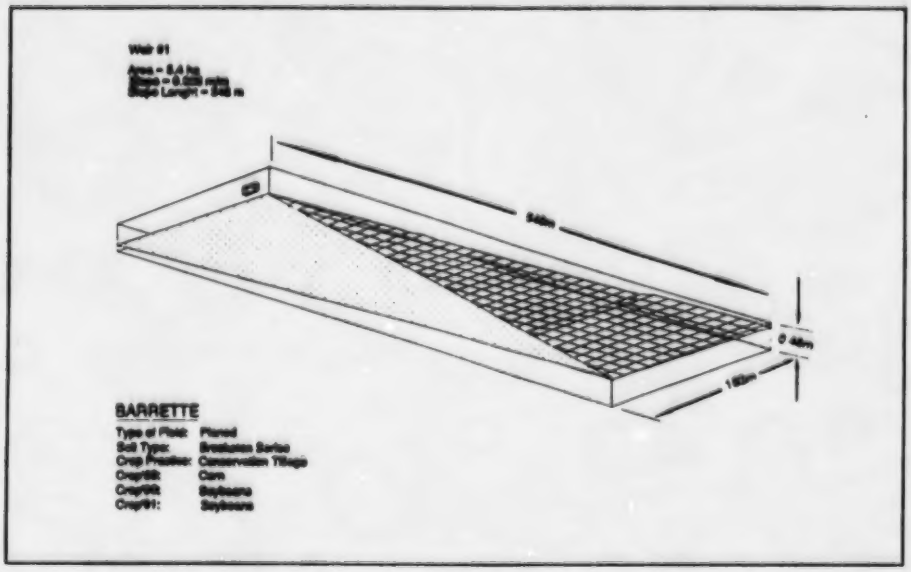

Figure 19. Site 3: Planed Field Drainage Basin Map.

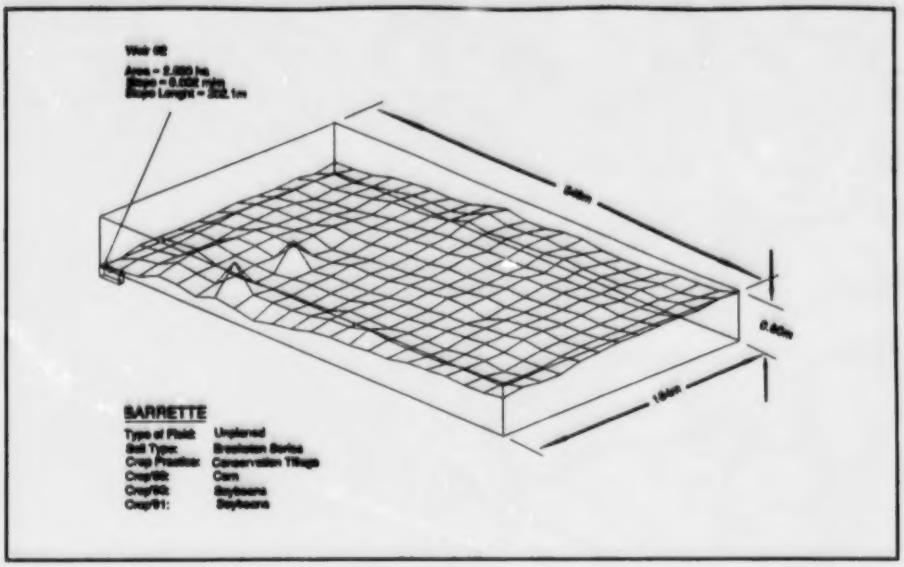

Figure 20. Site 3: Unplaned Field Topographic Map.

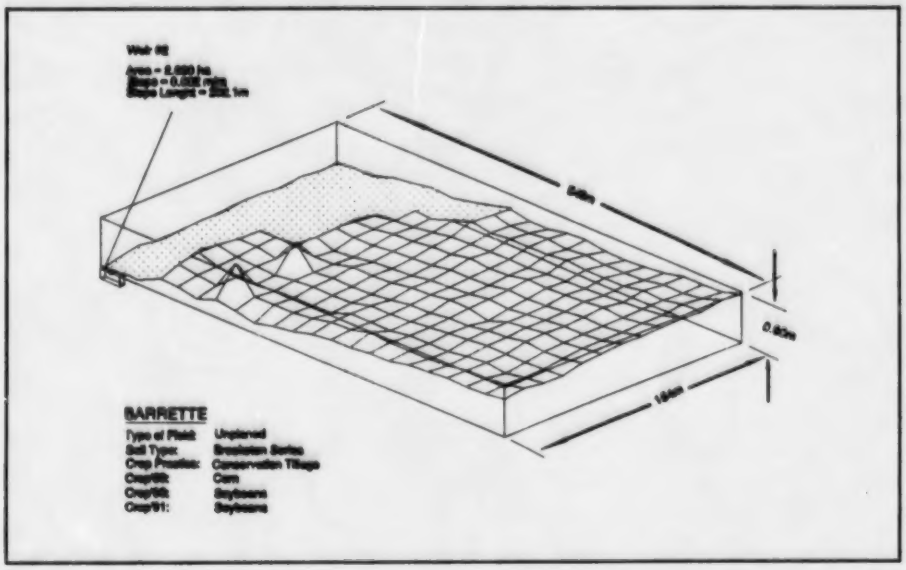

Figure 21. Site 3: Unplaned Field Drainage Basin Map.

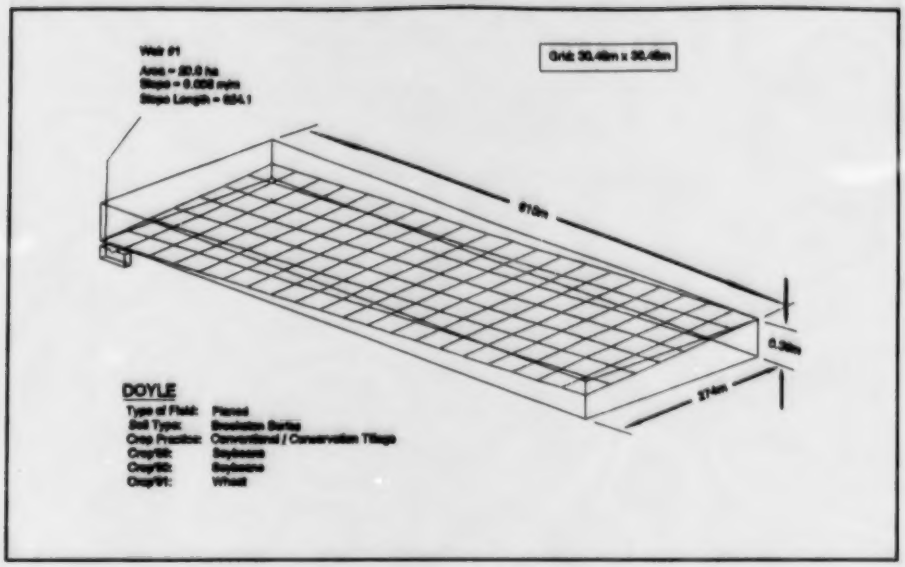

Figure 22. Site 4: Planed Field Topographic Map.

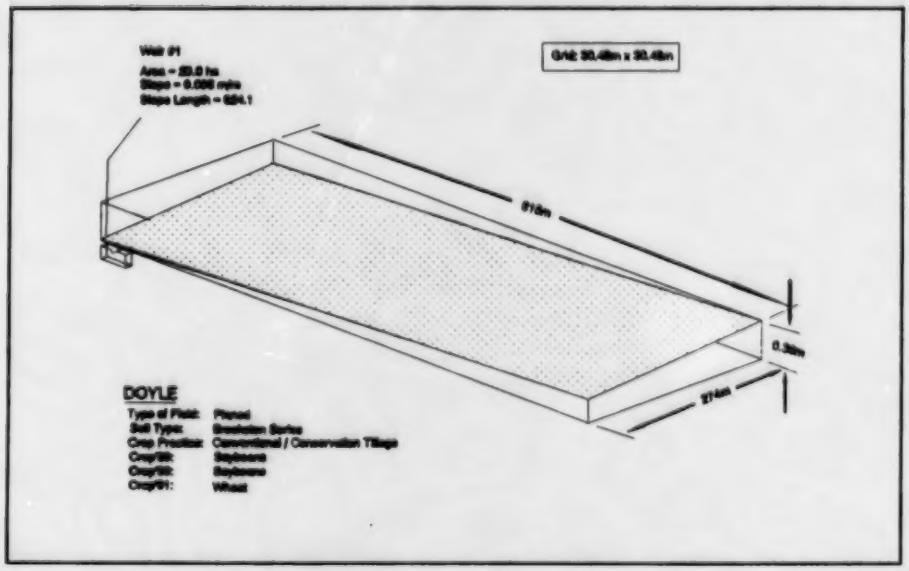

Figure 23. Site 4: Planed Field Drainage Basin Map.

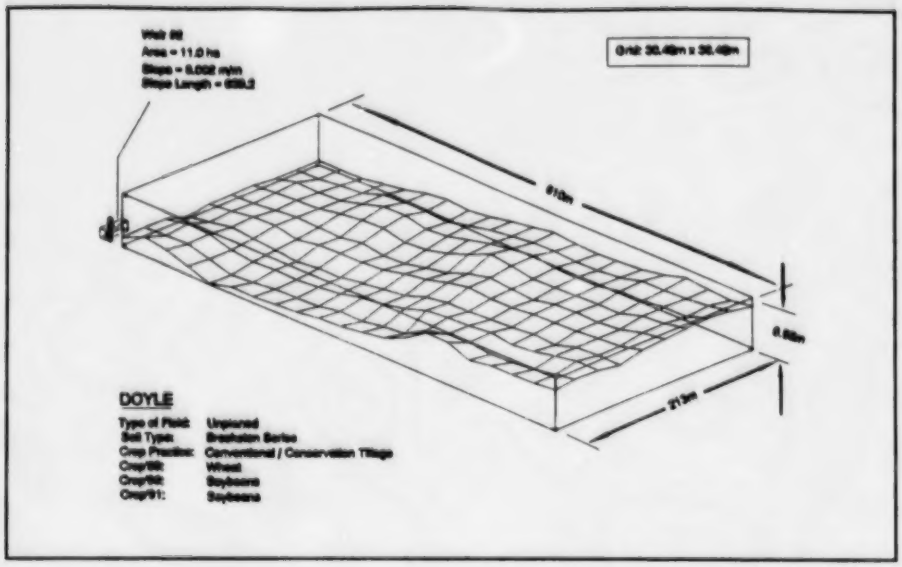

Figure 24. Site 4: Unplaned Field Topographic Map.

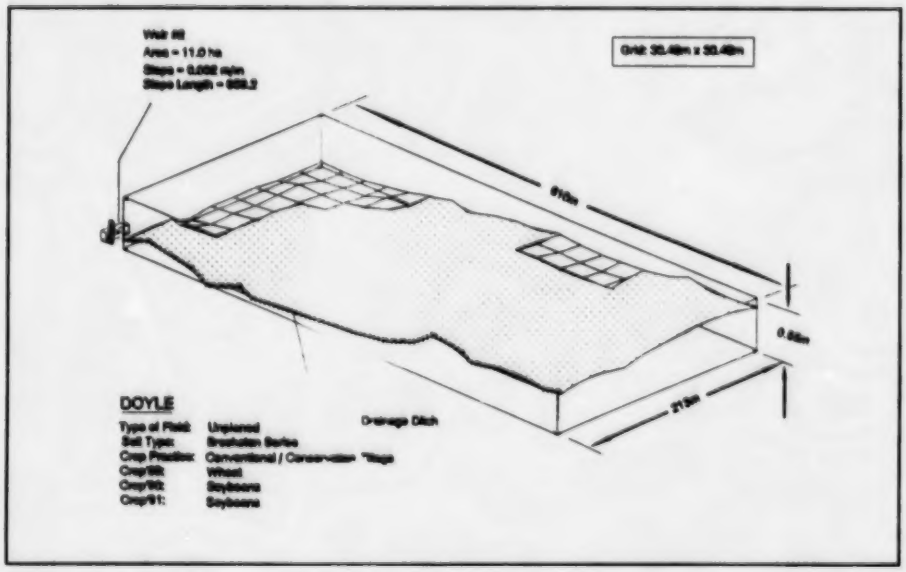

Figure 25 Site 4: Unplaned Field Drainage Basin Map.

3.2 CLIMATIC CONDITIONS

The monthly precipitation totals of the three sites are graphed in Figures 26 to 28. The data for the first two years at site 1 is from the Harrow Research Station (5 km from site 1). Any other missing totals were supplemented by data from the Harrow or Woodslee Research Stations (which ever was closer to the site).

Several precipitation trends can be determined from the graphs indicating: consistently greater amounts of precipitation in the months of April, May and June; lack of precipitation in the winter months; inconsistent summer totals due to intense localized thunderstorms; and greater overall precipitation levels closer to the southern end of Lake Erie (site 1).

The spring rains provide a needed soil recharge after the dry winter months. Occasionally, intense periods of rainfall, soon after planting, can harm the crop (as was the case in the spring of 89 at site 1 and site 4). The summer months are also subjected to intense downpours, but if the crop is established it will usually escape with little or no damage. Exceptions to this occur when the rain event leads to flooding which is quite prevalent in this region. During our first year of monitoring (1989), site 1 had severe flooding which caused extensive crop loss.

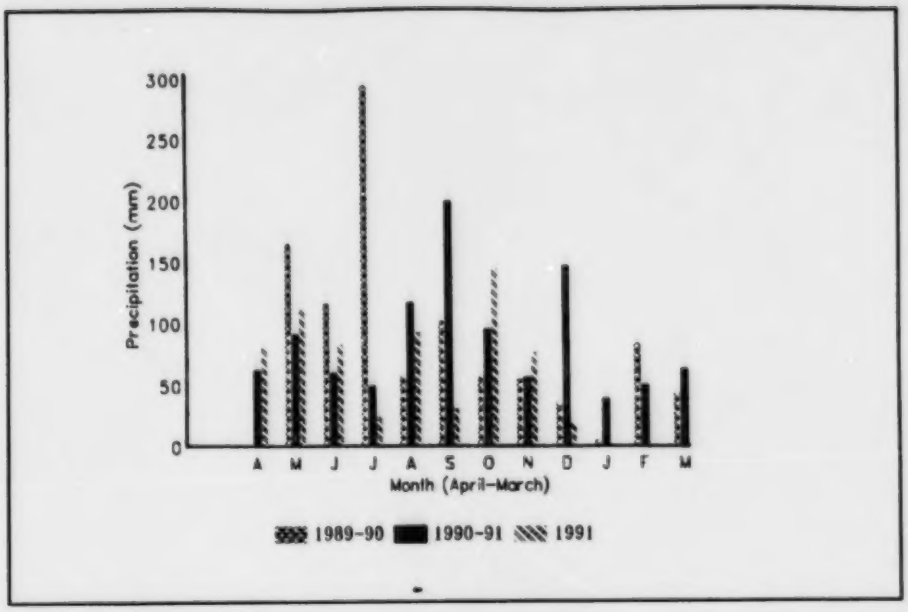

Figure 26. Recorded Precipitation at Site 1: 1989-91.

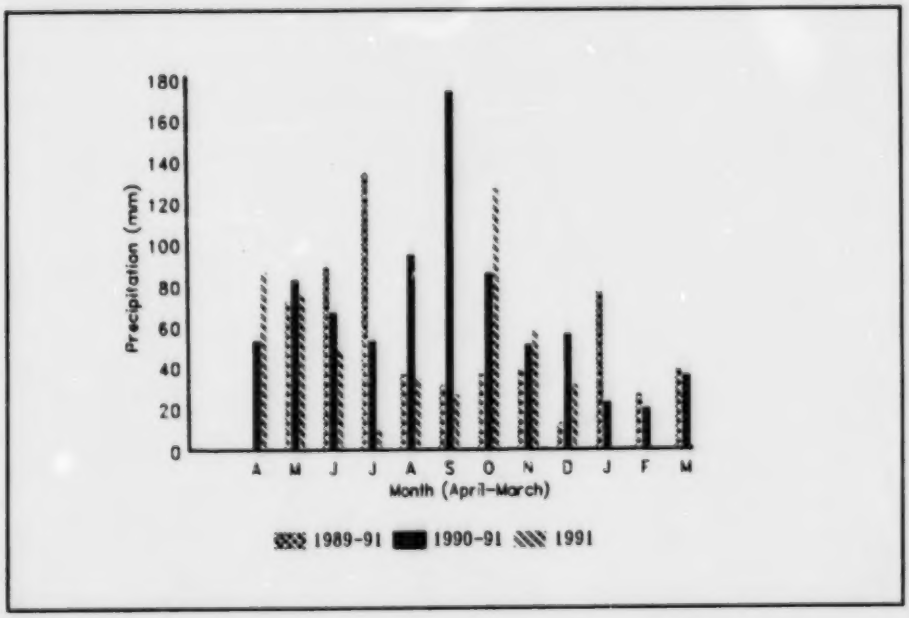

Figure 27. Recorded Precipitation at Site 2: 1989-91.

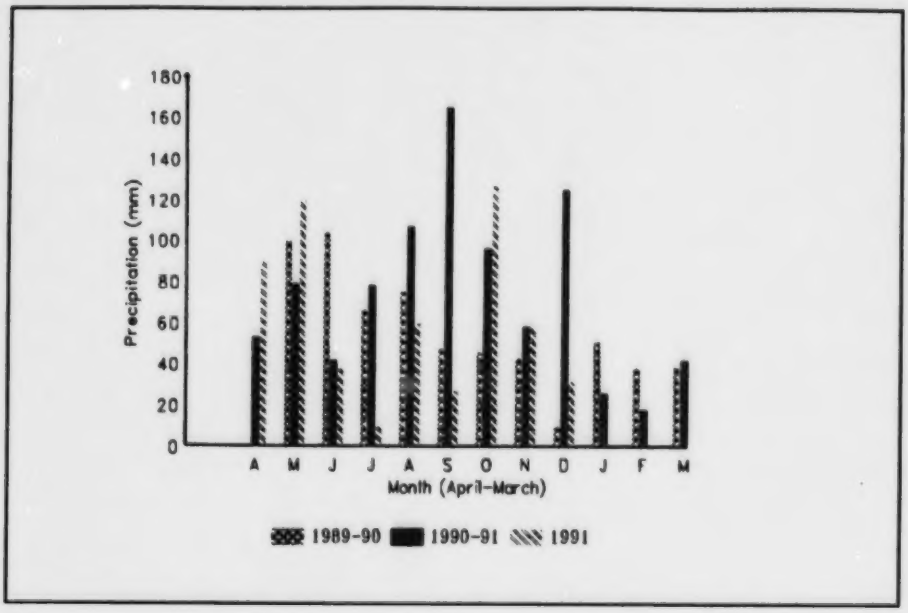

Figure 28. Recorded Precipitation at Site 4: 1989-91.

3.3 HYDROLOGY

3.3.1 Observations

Reviewing the hydrographs and the flow volume tables for numerous events produced some general observations for each site.

3.3.1.1 Site 1

At site 1 (Table 3 and Figures 29 to 39) the most predominant observation from the hydrographs is the excessive amount of runoff that flows through weir 4. The drainage basin that feeds weir 4 is by far the largest of the two fields, yet even when corrected for basin size (L/ha) it still has the greatest amount of runoff in most events. Several possibilities might account for this increased runoff, including: greater slopes around the drainage basin (natural topography), decreasing the infiltration rate (K) and therefore increasing the runoff; the large quantities of runoff drain into a certain section of the field forming a drainage trough, diminishing the infiltration capabilities and a saturation point is reached thus increasing the potential for surface runoff; and the estimated area of the basin may be in error since numerous drainage furrows run up and down the field altering the fragile micro-watersheds in these nearly flat fields. In this situation the natural topography is very prone to surface runoff and erosion.

The total runoff from the various events (Table 3) indicates that in all but one case, the unplaned field produced more runoff than the planed field. The runoff volumes (L/ha) from the planed field are similar to the volumes observed from the planed fields at the other sites where planing contributed more runoff. This is another indication that the natural surface drainage on the unplaned field at site 1 created excessive runoff. Forming smaller drainage basins, as on the planed field, with individual outlets prevented a major build-up of surface flow at one outlet. In theory though, the runoff rate per unit of area decreases as the size of the watershed increases because the larger watershed requires more time to accumulate runoff from all parts of the watershed and therefore a longer rain is needed to produce maximum runoff. This theory is

Table 3. Site 1 Event Flow Volumes.

Event D/M/Y	Field	Area (ha)	Rainfall (mm)	Duration (hrs)	Previous five day rainfall accumulation (mm)	Runoff (L/ha)	Start Time*	Time to Peak (hrs)*
190789	Planed	8.4	270	13	2	4,557,426	11:00 p.m.	13.3
	Unplaned	44.9				2,930,549	11:40 p.m.	14.3
100490	Planed	8.4	26	25	10	4,084	10:43 a.m.	4.3
	Unplaned	44.9				9,469	11:55 a.m.	6.7
140490	Planed	8.4	8	8	27	Trace	-	-
	Unplaned	44.9				1,241	6:00 a.m.	2.0
200490	Planed	8.4	15	11	1.5	Trace	-	-
	Unplaned	44.9				4,422	11:50 a.m.	3.0
160590	Planed	8.4	24	22	38	5,565	6:18 a.m.	2.0
	Unplaned	44.9				12,447	8:45 a.m.	3.3
190890	Planed	8.4	38	39	89	Trace	-	-
	Unplaned	44.9				12,494	4:00 a.m.	13.0
060990	Planed	8.4	97	15	0	463,295	4:00 p.m.	5.0
	Unplaned	24.5				1,224,734	4:00 p.m.	9.0
140990	Planed	8.4	41	3.5	4	Trace	-	-
	Unplaned	24.5				174,318	2:00 p.m.	10.0
190491	Planed	8.4	50	24	1	1,202	4:30 p.m.	11.0
	Unplaned	24.5				13,731	4:30 p.m.	6.0
310591	Planed	8.4	24	25	30	39,192	7:00 p.m.	1.0
	Unplaned	24.5				64,266	7:00 p.m.	3.0
251091	Planed	8.4	68	41	31	289	9:00 p.m.	7.0
	Unplaned	24.5				2,159	10:00 p.m.	3.0

* average of three weirs on each field

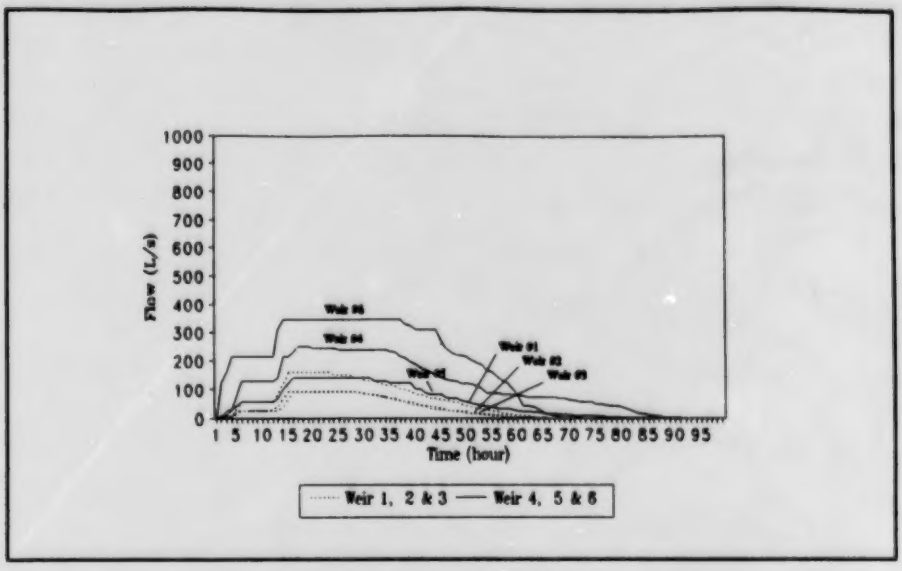

Figure 29. Site 1: Hydrograph (July 20/89).

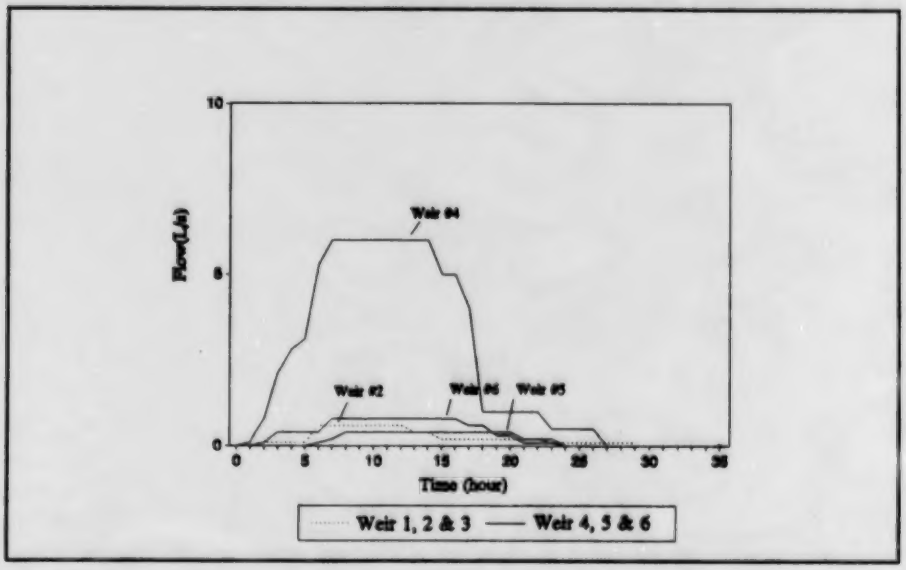

Figure 30. Site 1: Hydrograph (April 10/90).

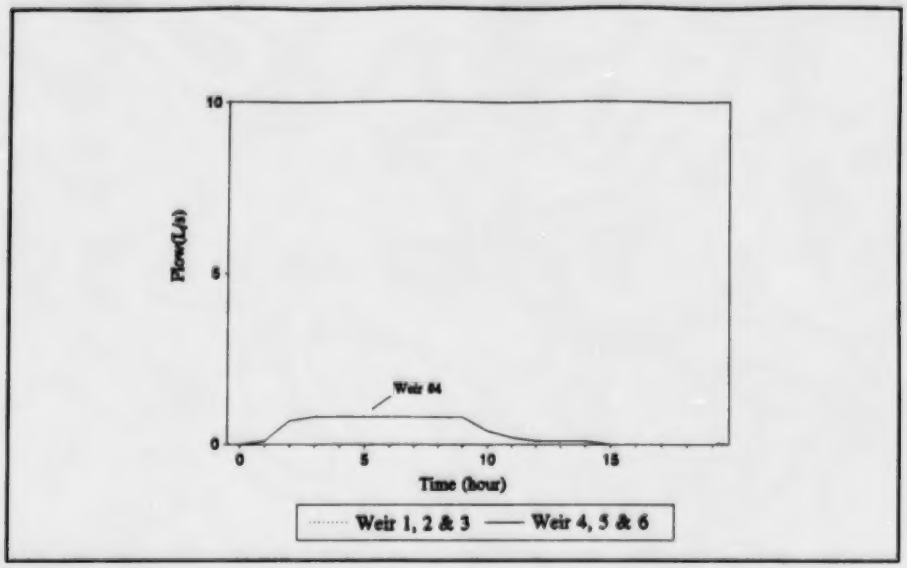

Figure 31. Site 1: Hydrograph (April 14/90).

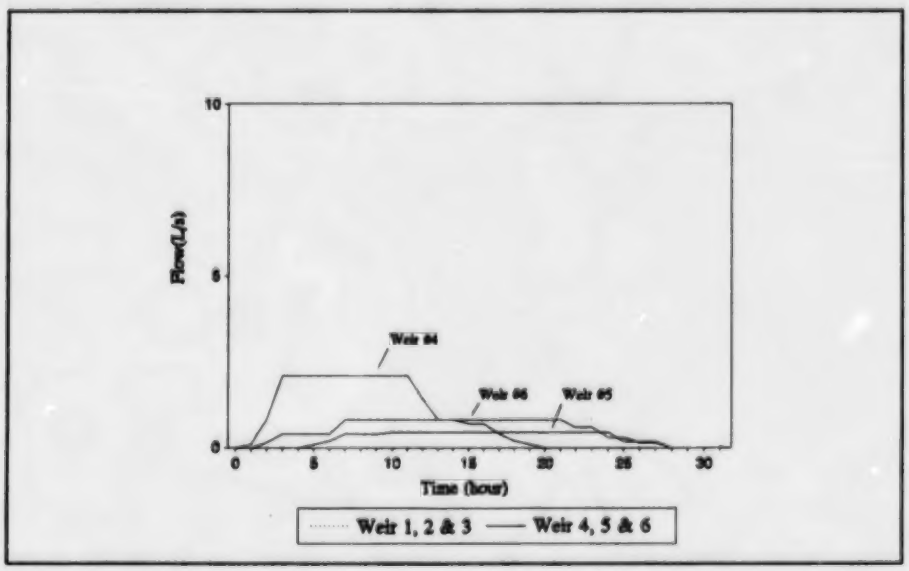

Figure 32. Site 1: Hydrograph (April 20/90).

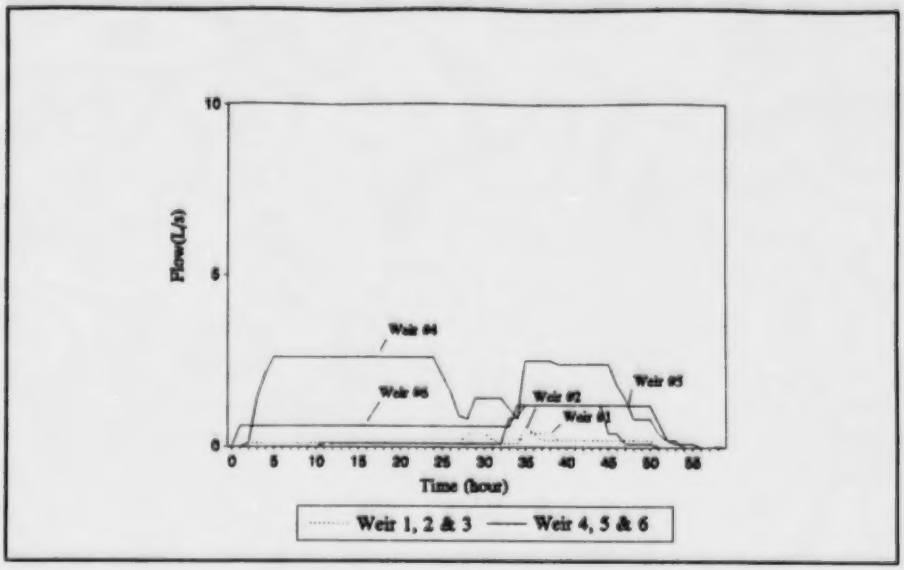

Figure 33. Site 1: Hydrograph (May 16/90).

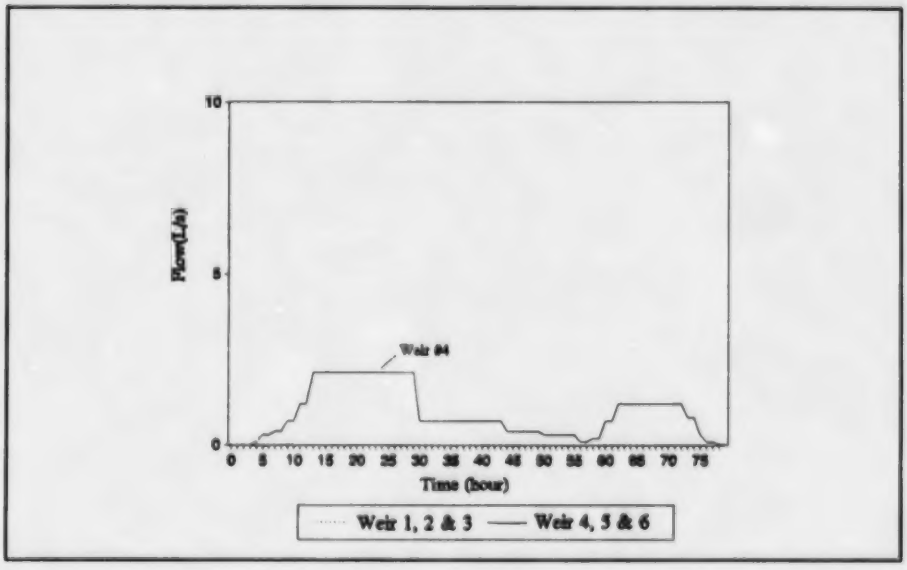

Figure 34. Site 1: Hydrograph (August 19/90).

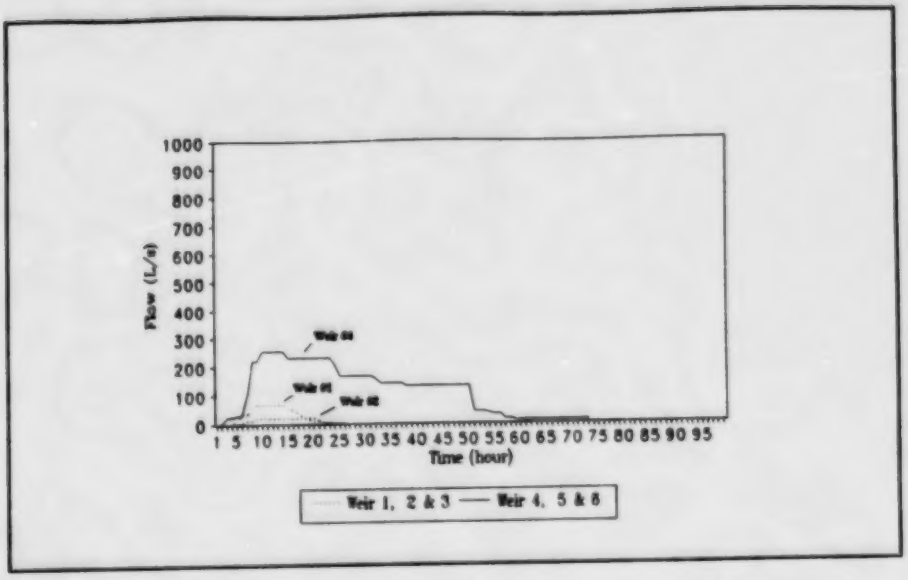

Figure 35. Site 1: Hydrograph (September 06/90).

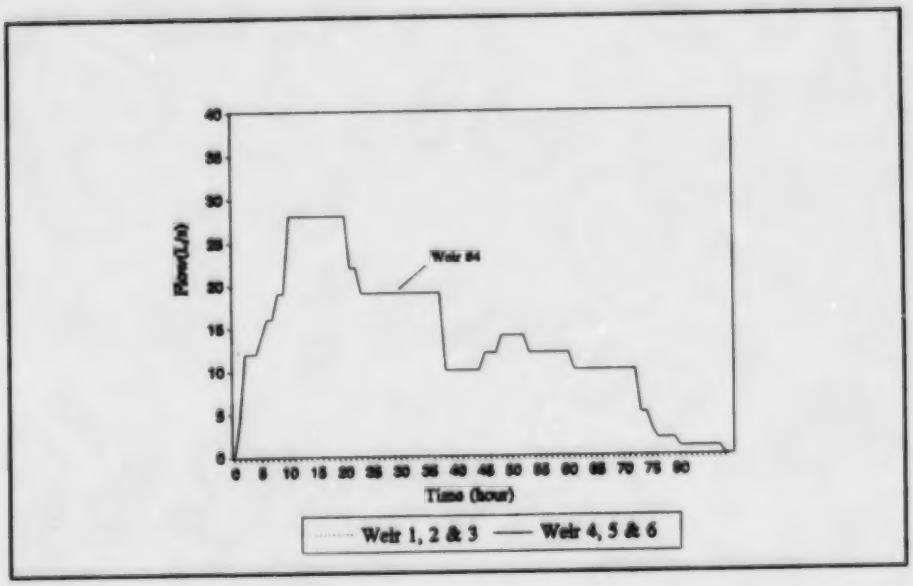

Figure 36. Site 1: Hydrograph (September 14/90).

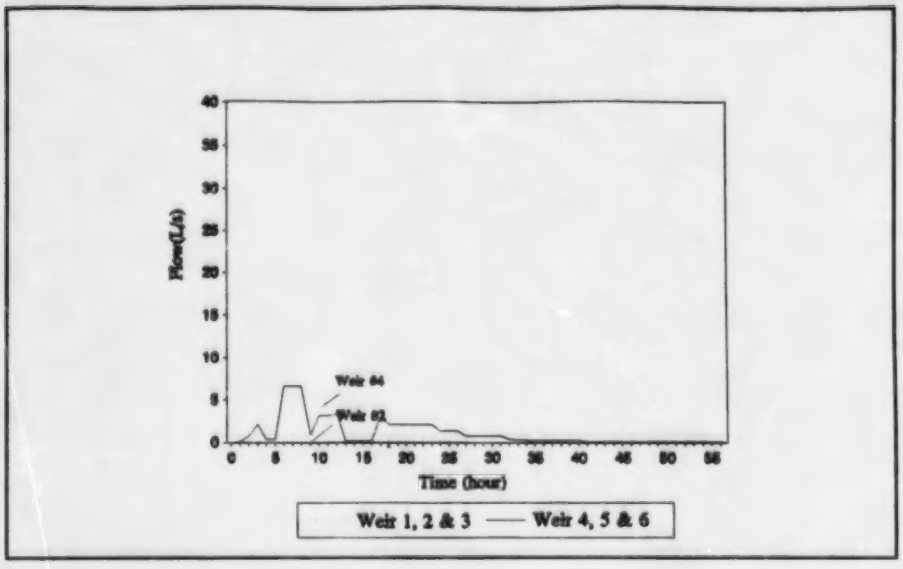

Figure 37. Site 1: Hydrograph (April 19/91).

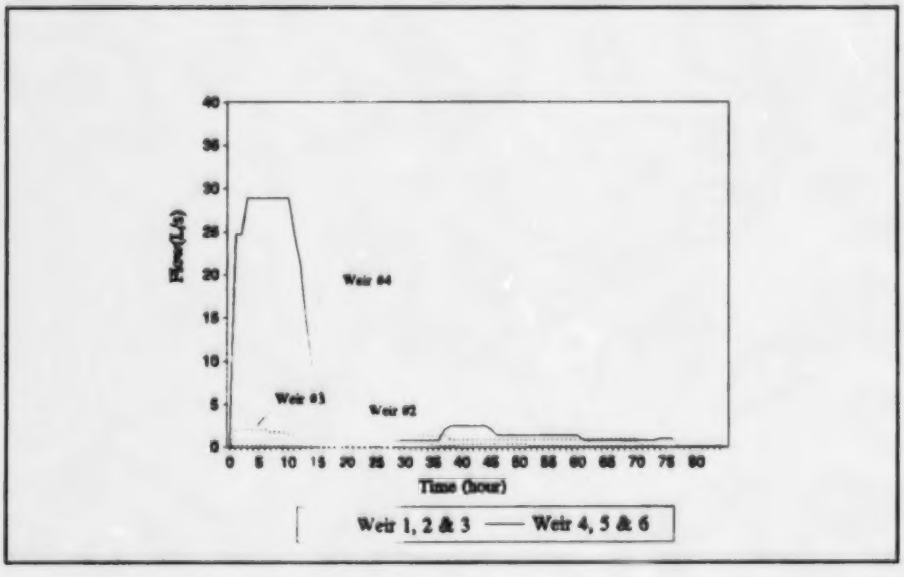

Figure 38 Site 1: Hydrograph (May 31/91).

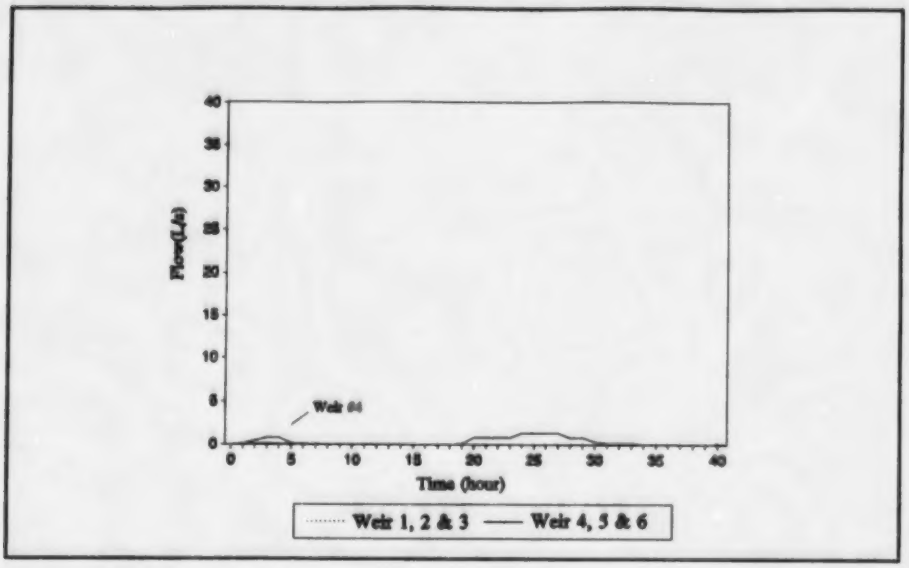

Figure 39. Site 1: Hydrograph (October 25/91).

based on natural depressions holding back the flow of excess surface water, however, on planed fields these depressions are eliminated. Therefore, smaller basins on a planed field may reduce runoff compared to larger basins on a planed field due to reduced slope length and increased infiltration (less accumulation of surface water).

The most obvious exception to the trend occurred in the flood producing storm in July 1989. The exact volumes generated during this event can not be determined since the water height exceeded the weir height. The reported values for this event, however, provide an estimate as to the performance of each field even though the volumes exceed the rainfall amount. The probable key reason that the planed field contributed greater runoff during this event was the lack of a vegetation cover which was destroyed in an earlier event (only on the planed field).

Another trend at site 1 is the delayed "time to peak" during an event. This was expected on the unplaned field since the watershed is quite large and therefore requires more time to produce runoff from all parts of the watershed and thus a longer time to reach maximum runoff. The lag in "time to peak" on the smaller planed areas is difficult to explain. Rainfall intensity can alter the peak times, less intensity - longer to peak, but it would be a constant between the two fields. The actual start of the runoff (start time) appears to occur earlier on the planed field due to the lack of natural water retaining depressions that are eliminated by planing.

3.3.1.2 Site 2

At site 2 the flow table and hydrographs (Table 4 and Figures 40 to 47) indicate greater runoff from the planed field in the majority of events. The most obvious anomaly to the trend was the 100490 event, where the recorded runoff volume far exceeded the actual rainfall amount. This was caused by additional runoff from the adjacent field flowing around a damaged berm and through weir 2 (unplaned field). Several reasons, some already

Table 4. Site 2 Event Flow Volumes.

Event D/M/Y	Field	Area (ha)	Rainfall (mm)	Duration (hrs)	Previous five day rainfall accumulation (mm)	Runoff (L/ha)	Start Time	Time to Peak (hrs)
190689	Planed	1	38	3	13	22,259	5:30 p.m.	1
	Unplaned	1				5,025	6:00 p.m.	1
260689	Planed	1	14	2	38	30,706	9:30 p.m.	1
	Unplaned	1				820	9:00 p.m.	1
200789	Planed	1	102	14	0	186,847	4:30 a.m.	2
	Unplaned	1				11,428	5:00 a.m.	2
260789	Planed	1	30	4	0	191,301	7:00 p.m.	1
	Unplaned	1				54,128	7:45 p.m.	1
100490*	Planed	6	17	17	3	3,135	3:15 p.m.	3
	Unplaned	4				821,285	5:15 p.m.	1
150590	Planed	6	32	12	0	39,602	7:00 p.m.	7
	Unplaned	4				12,447	7:00 p.m.	1**
070990	Planed	6	71	12	0	9,221	1:00 a.m.	2
060990	Unplaned	4				12,977	11:00 p.m.	3
140990	Planed	6	55	2	8	12,541	1:00 p.m.	3
	Unplaned	4				7,582	3:00 p.m.	1

* Results appear to be an anomaly caused by runoff from an adjacent field to the unplaned field.

** Second peak after 30 hours (after additional rain)

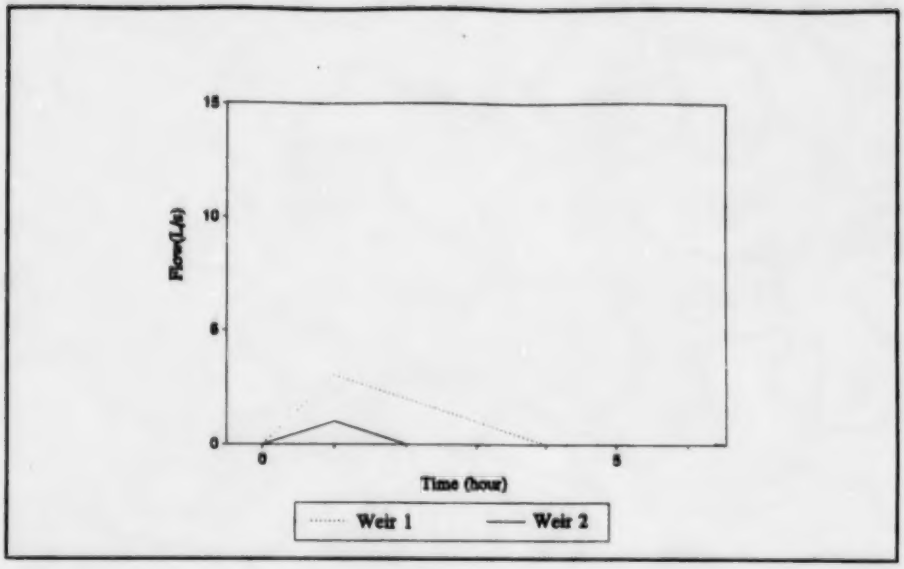

Figure 40. Site 2: Hydrograph (June 19/89).

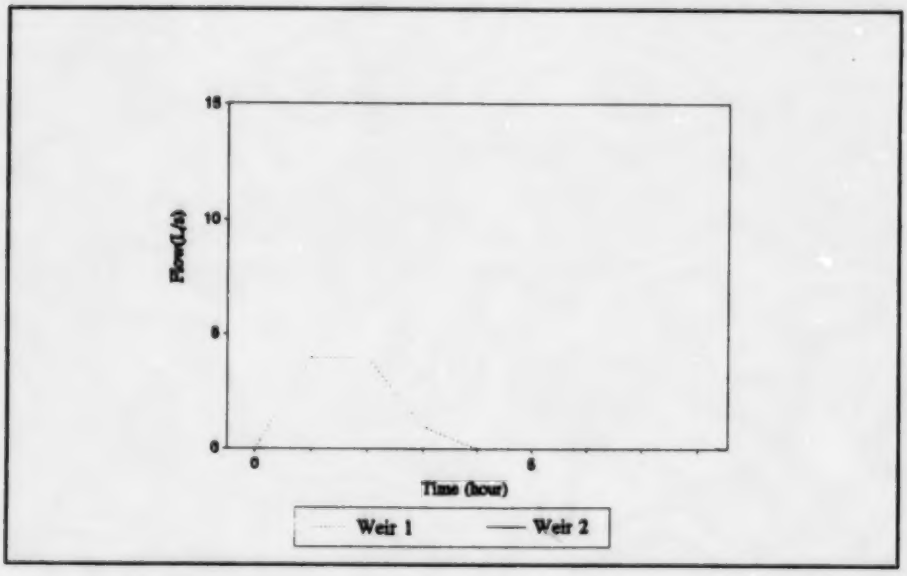

Figure 41. Site 2: Hydrograph (June 26/89).

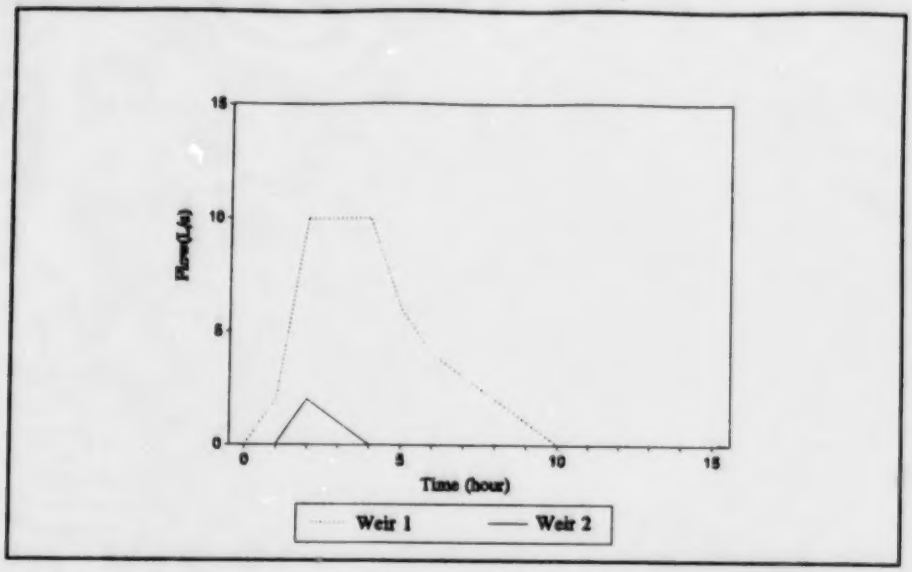

Figure 42. Site 2: Hydrograph (July 20/89).

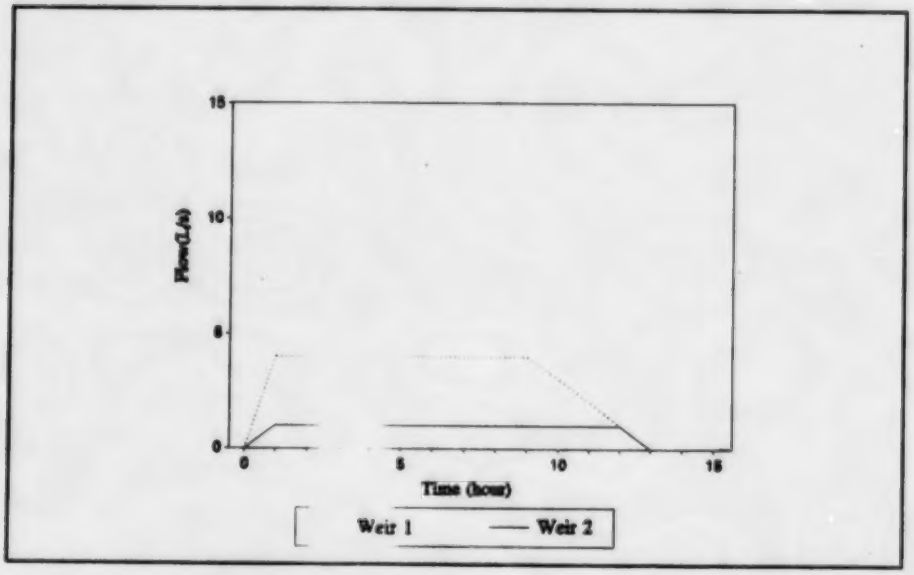

Figure 43. Site 2: Hydrograph (July 26/89).

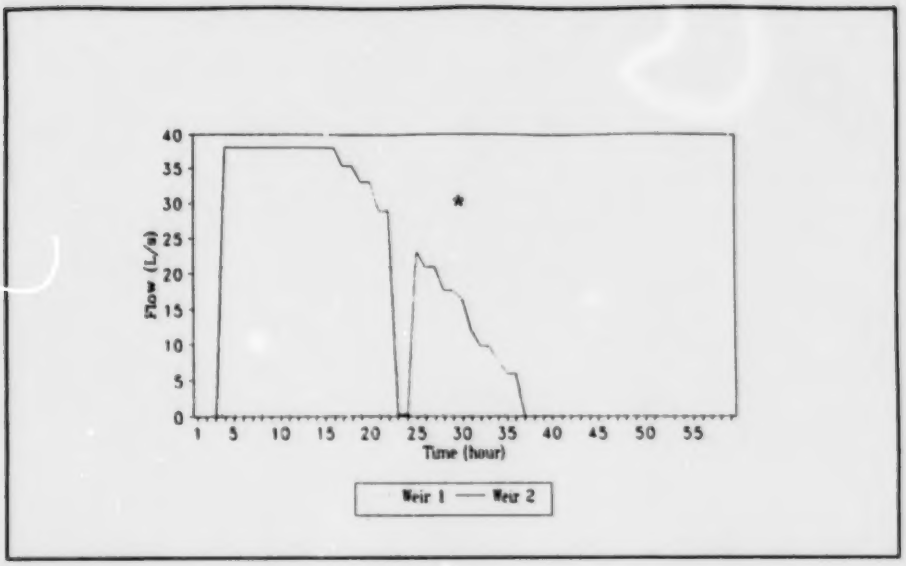

Figure 44. Site 2: Hydrograph (April 10/90).
* runoff from adjacent field contributed to volumes

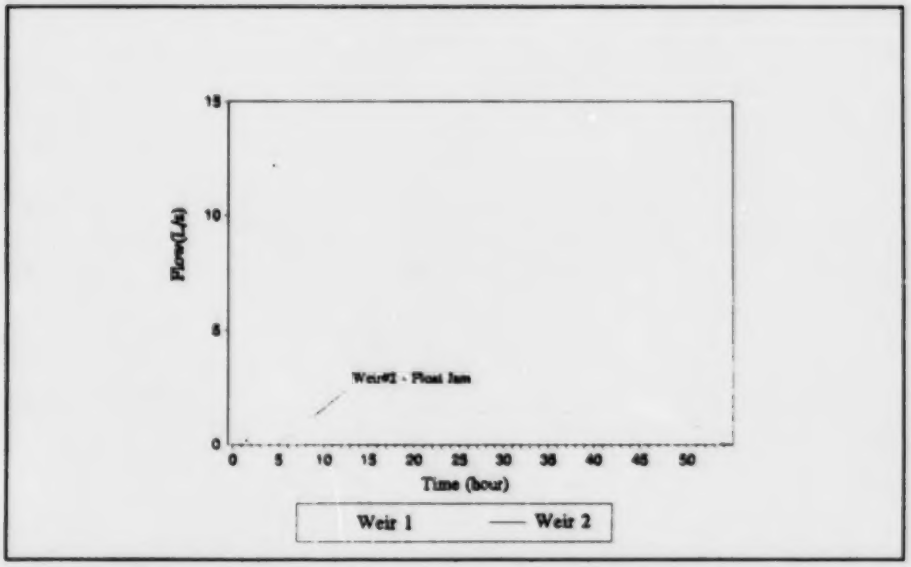

Figure 45. Site 2: Hydrograph (May 15/90).

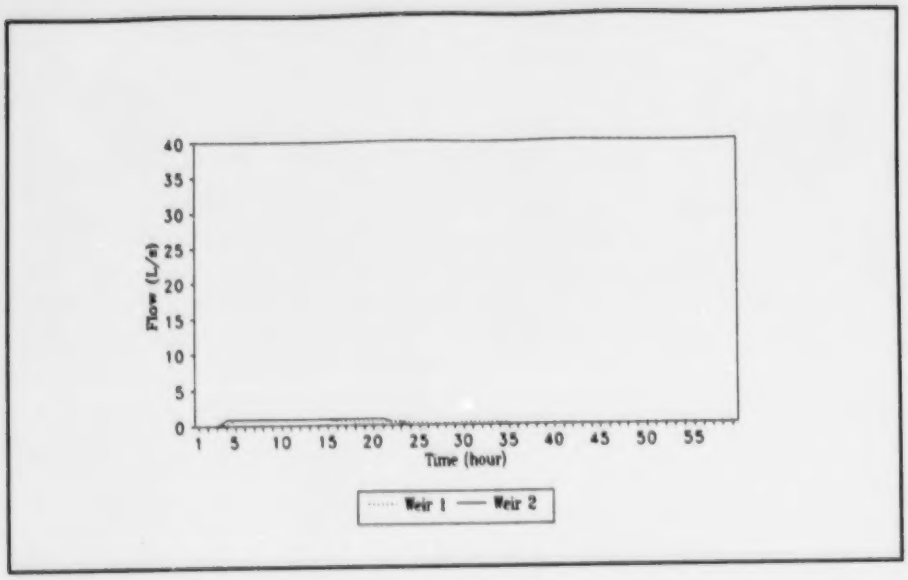

Figure 46. Site 2: Hydrograph (September 7/90).

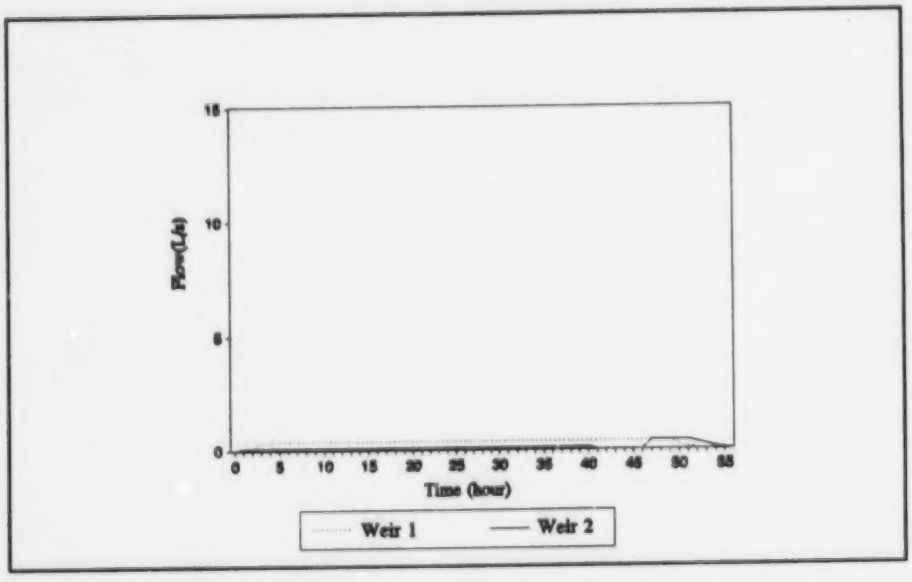

Figure 47. Site 2: Hydrograph (September 14/90).

mentioned can account for greater runoff from a planed field. These include: the elimination of depressional areas where water can infiltrate; the construction of the uniform slope which may result in a longer and steeper slope increasing water velocity and decreasing infiltration; and the physical alteration of the soil in the "cut and fill" procedure may reduce natural soil voids and thus once again reduce water infiltration which results in greater surface water runoff.

In the first year site 2 was in tomatoes, therefore equal drainage areas could be created on both fields by berming off an equal number of rows. The first four events recorded in Table 4 associated with the equal basins clearly demonstrate an increased volume of runoff from the planed field.

The "start time" and "time to peak" data are similar between the two fields except in the last few events where the planed field lagged behind the unplaned. This lag in the "time to peak" effect is probably due to the affect that a less intense rain storm has on the larger drainage basin of the planed field.

3.3.1.3 Site 3

The flow data (Table 5) and hydrographs (Figures 48 to 55) from site 3 demonstrate a similar pattern to site 2. The planed field had much greater runoff volumes than the unplaned field. The "start time" and "time to peak" data, again are relatively equal between fields. As mentioned above, a slight lag in "time to peak" on the planed field with some of the earlier events which may be due to the larger basin size (planed: 5.4 ha, unplaned: 2.6 ha).

3.3.1.4 Site 4

Collection of quality paired event data has been difficult at this site (Table 6 and Figures 56 to 62). The weir on the planed field was washed out numerous times over the past three years. This points out a possible design problem when using weirs without a proper control structure (i.e. weir with cement flow channel and sides). A small flume may have been more

Table 5. Site 3 Event Flow Volume.

Event D/M/Y	Field	Area (ha)	Rainfall (mm)	Duration (hrs)	Previous five day rainfall accumulation (mm)	Runoff (L/ha)	Start Time	Time to Peak (hrs)
190689	Planed	5.4	38	3	13	144,756	8:00 p.m.	2
	Unplaned	2.6				68,094	7:00 p.m.	1
230689	Planed	5.4	4	2	38	9,647	6:00 p.m.	2
	Unplaned	2.6				888	5:00 p.m.	1
200789	Planed	5.4	102	14	0	116,193	4:00 a.m.	4
	Unplaned	2.6				38,668	5:00 a.m.	2
260789	Planed	5.4	30	4	0	126,082	8:00 p.m.	3
	Unplaned	2.6				42,585	8:00 p.m.	2
160590	Planed	5.4	32	12	0	1,175	5:00 a.m.	2
	Unplaned	2.6				2,839	9:00 a.m.	1
070990	Planed	5.4	71	12	0	8,502	1:00 a.m.	1
	Unplaned	2.6				2,473	2:00 a.m.	2
140990	Planed	5.4	55	2	8	13,053	1:00 a.m.	2
	Unplaned	2.6				Trace	-	-
091090	Planed	5.4	51	55	24	19,068	6:00 a.m.	1
	Unplaned	2.6				Trace	-	-

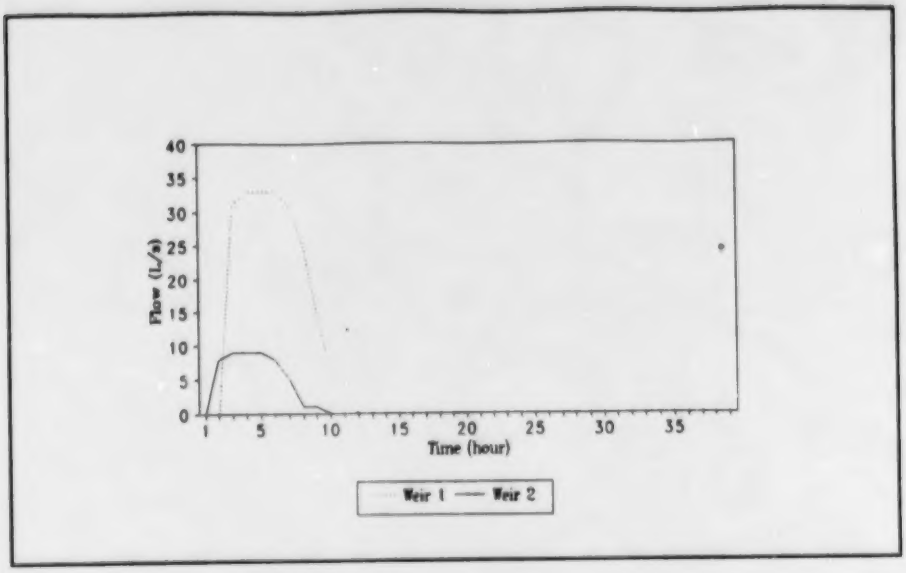

Figure 48. Site 3: Hydrograph (June 19/89).

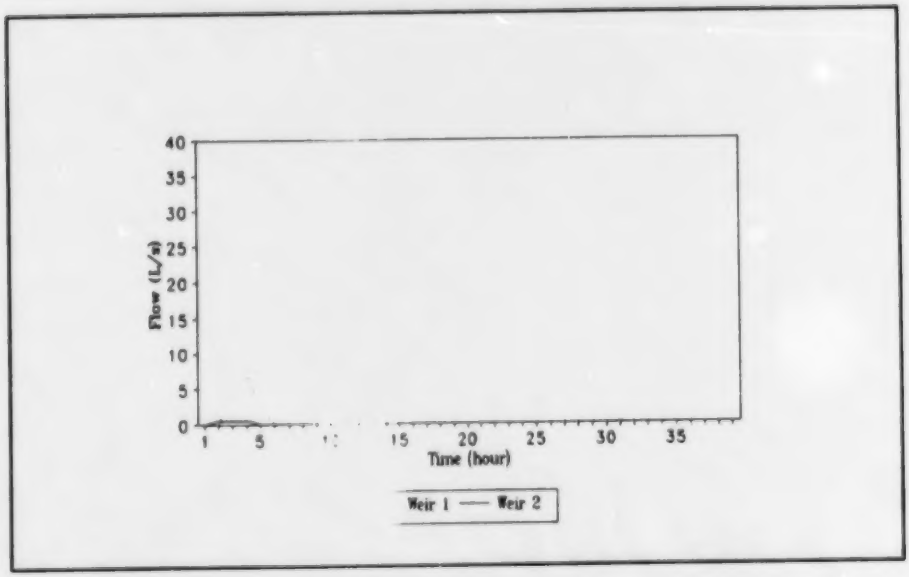

Figure 49 Site 3: Hydrograph (June 23/89).

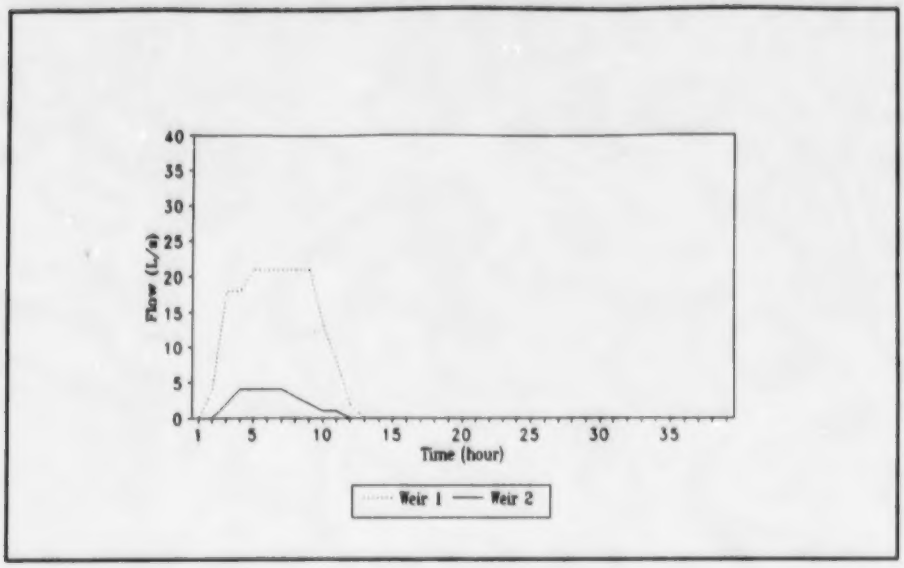

Figure 50. Site 3: Hydrograph (July 20/89).

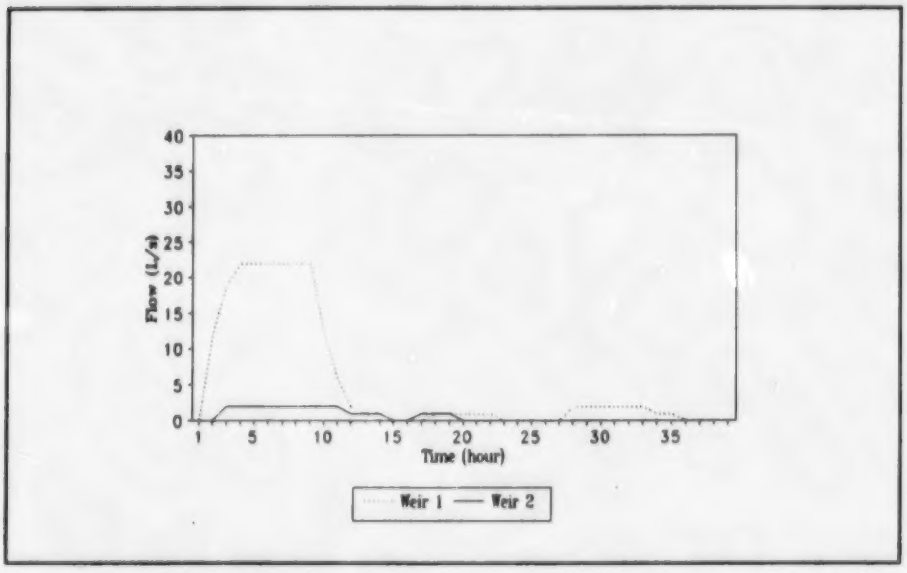

Figure 51. Site 3: Hydrograph (July 26/89).

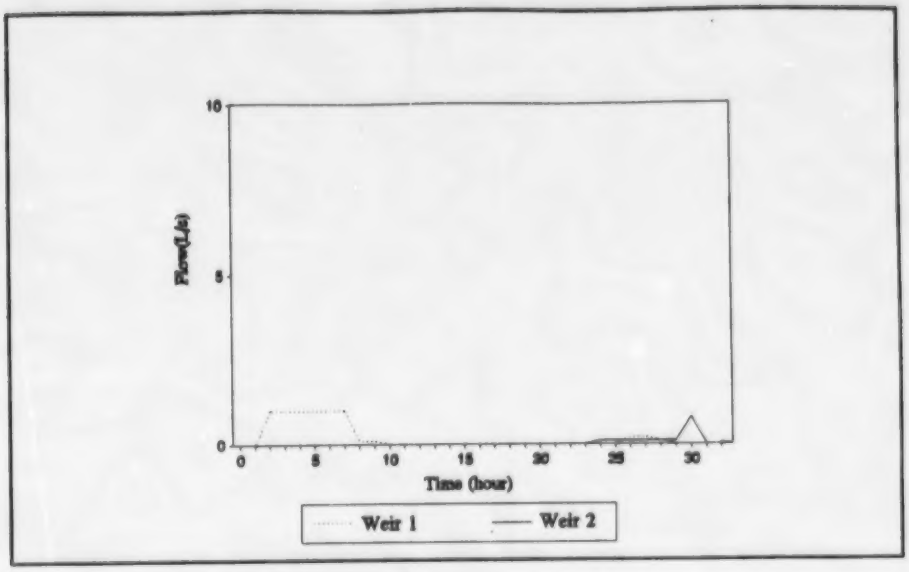

Figure 52. Site 3: Hydrograph (May 16/90).

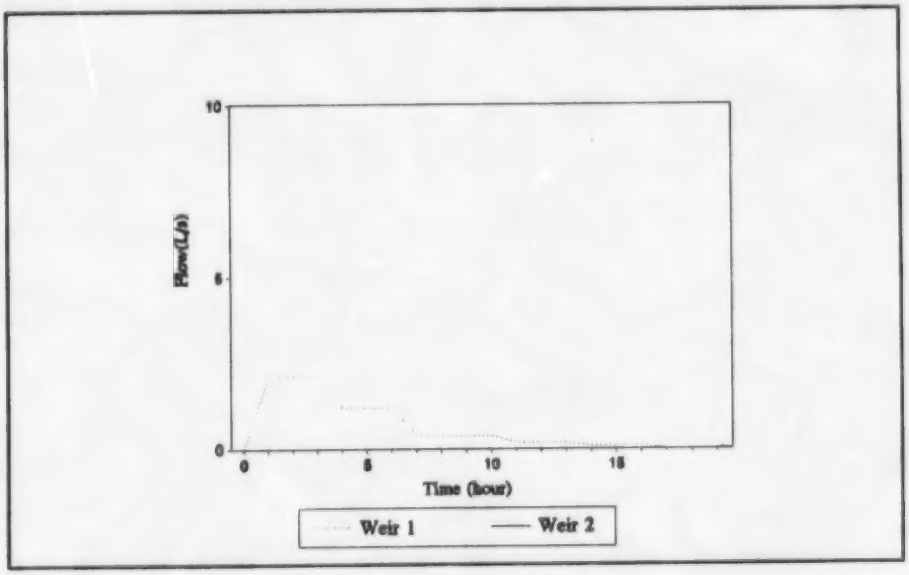

Figure 53. Site 3: Hydrograph (September 7/90).

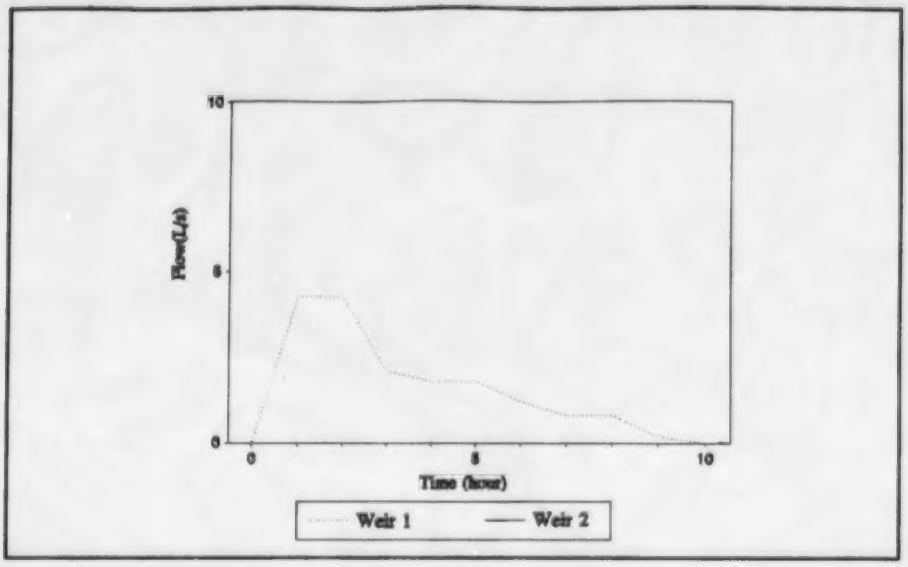

Figure 54. Site 3: Hydrograph (September 14/90).

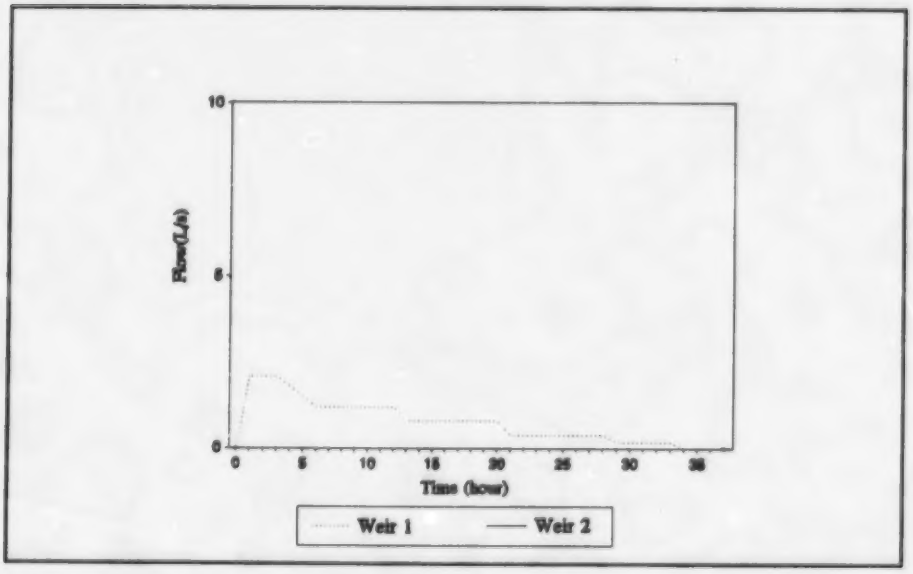

Figure 55. Site 3: Hydrograph (October 9/90).

Table 6. Site 4 Event Flow Volumes.

Event D/M/Y	Field	Area (ha)	Rainfall (mm)	Duration (hrs)	Previous five day rainfall accumulation (mm)	Runoff (L/ha)	Start Time	Time to Peak (hrs)
250589	Planed	20	60	21	13	*	9:30 p.m.	1
	Unplaned	11				472,325	11:00 p.m.	2
310589	Planed	20	46	25	60	*	-	-
	Unplaned	11				16,118	6:00 a.m.	2
190890	Planed	20	27	32	44	**	-	-
	Unplaned	11				13,884	2:00 a.m.	3
280890	Planed	20	27	19	0	**	-	-
	Unplaned	11				140,311	10:00 p.m.	2
060990	Planed	20	71	11	0	**	-	-
	Unplaned	11				***	11:00 p.m.	5
140990	Planed	20	48	10	8	**	-	-
	Unplaned	11				***	5:00 p.m.	2
210990	Planed	20	(9)	(4)	29	1,579,962	7:00 p.m.	5
	Unplaned	11				***	-	-

* weir wash-out

** flow recorder failure

*** ditch back-up

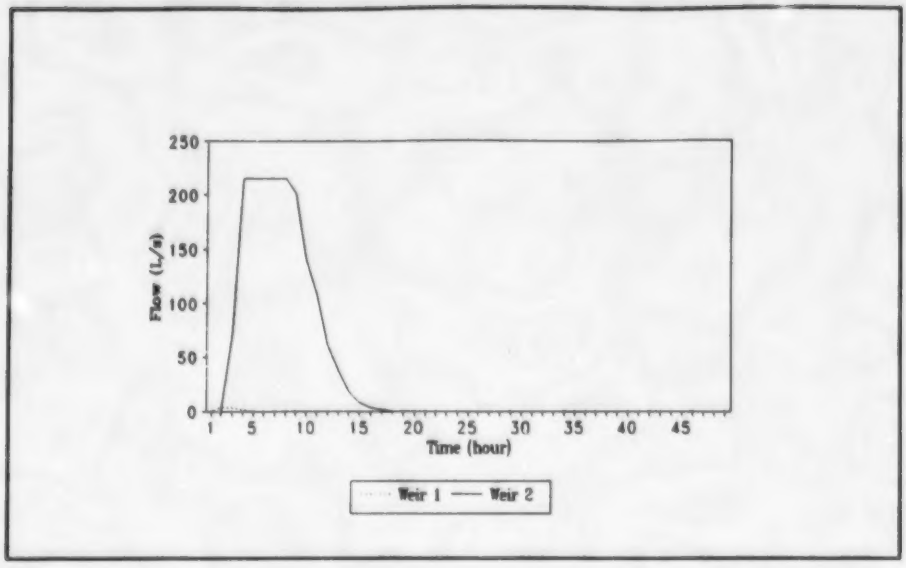

Figure 56. Site 4: Hydrograph (May 25/89).

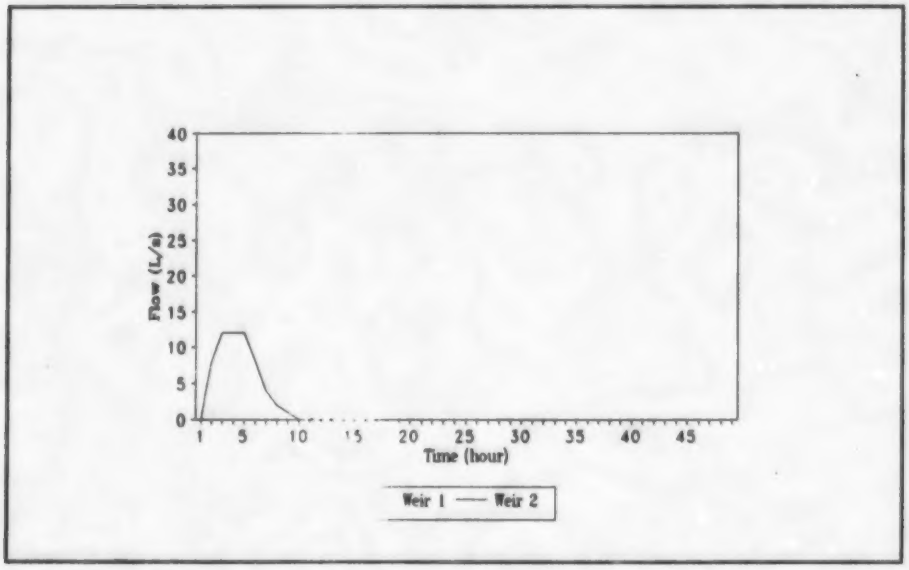

Figure 57. Site 4 Hydrograph (May 31/89).

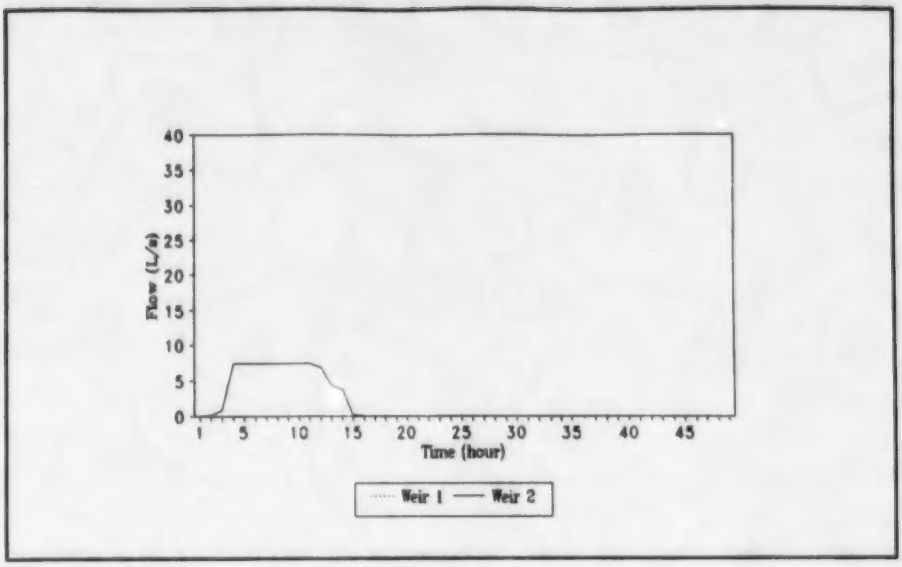

Figure 58. Site 4: Hydrograph (August 19/90).

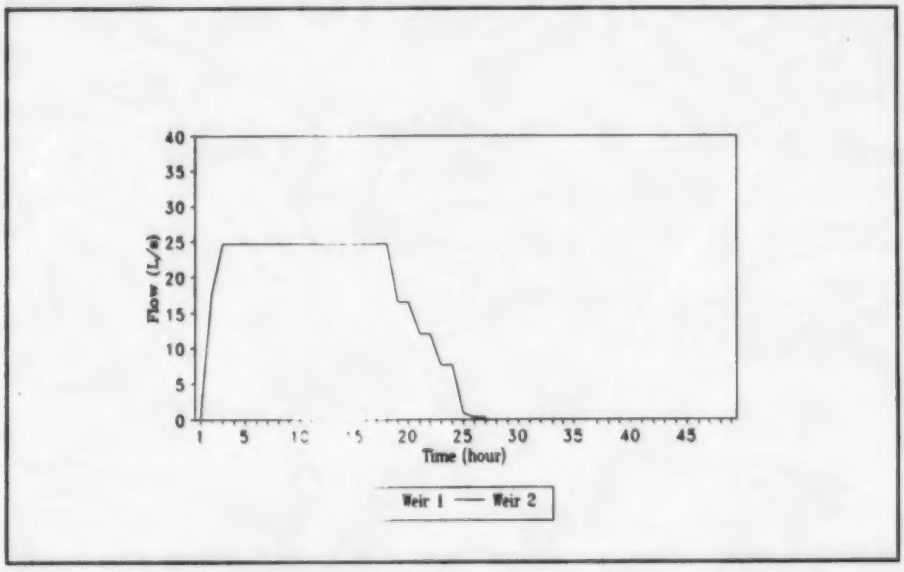

Figure 59 Site 4 Hydrograph (August 28/90).

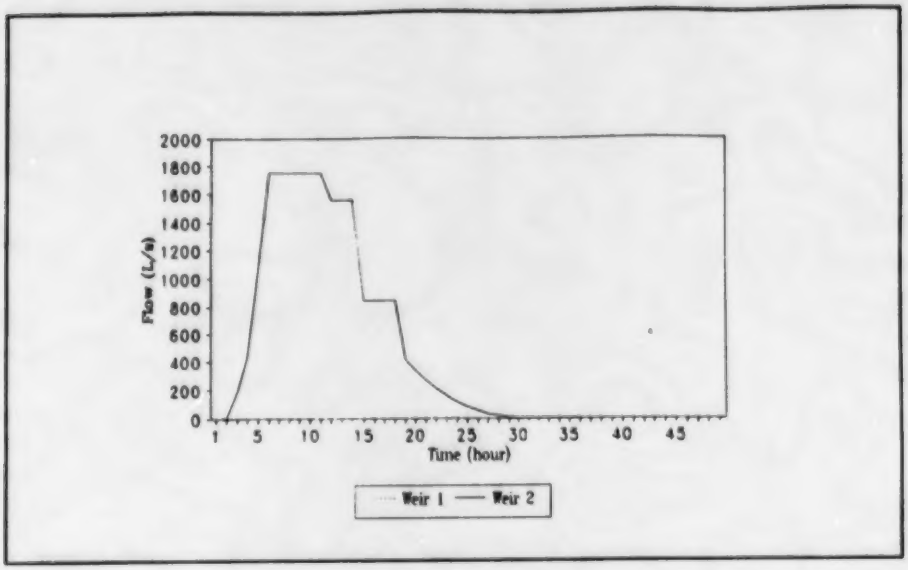

Figure 60. Site 4: Hydrograph (September 6/90).

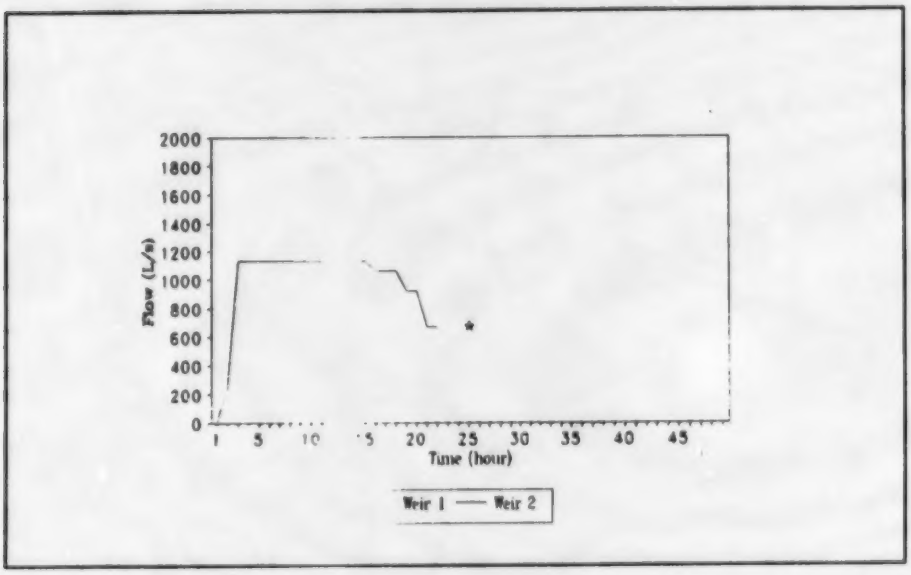

Figure 61 Site 4 Hydrograph (September 14/90).
* .. order failure

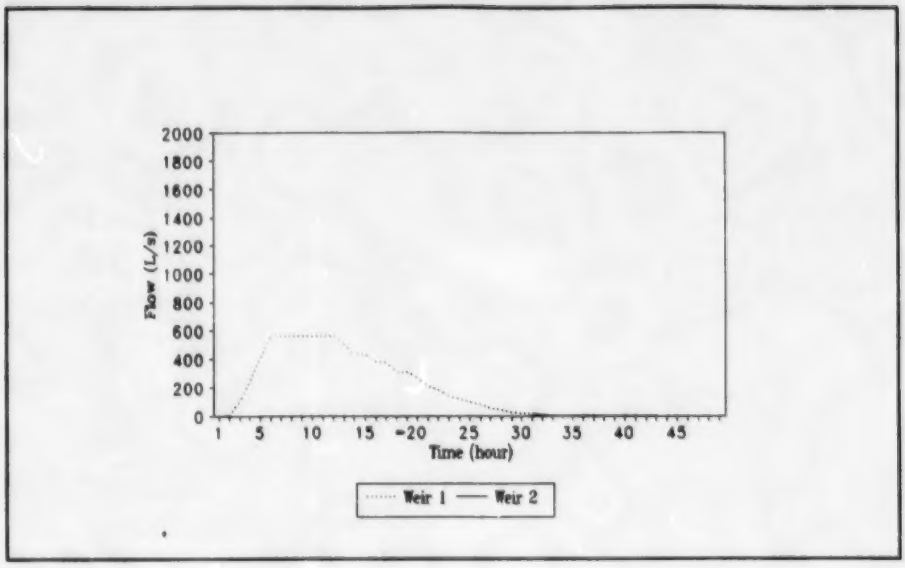

Figure 62. Site 4: Hydrograph (September 21/90).

appropriate for use in outlets with strong flows such as this one. The 210990 event revealed the immense volume that can flow through the planed field weir. This field demonstrated the design problem encountered when a uniform slope with one outlet is used on a large area. Eliminating the uniform slope and planing to form two or more slope directions (each with its own outlet), would create a more complex topography which best fits the natural shape. This would reduce the depths of the cuts and fills as well as decreasing the runoff at each drainage outlet.

3.3.2 Discussion

Overall, a couple of similar trends were observed at all sites. The majority of recorded events occurred in the spring and early summer as well as the early fall. This corresponds to the precipitation charts discussed earlier. The occasional intense summer thunderstorm also produced a runoff event but the erosive nature of the storm was reduced due to the vegetation cover. Runoff is also associated with: winter rains as the water flows over the frozen soil; and the melting of snow accumulations. Our instrument had difficulties in recording winter events because the stillwell float would freeze in the inlet tube trap and therefore no pen movement occurred.

The other constant between sites was the hydrograph shapes. All sites experienced a curved peak with an easily distinguishable maximum flow and a flat top peak where maximum flow appeared constant for two or more hours. The curved peak was expected but the creation of the flat top hydrograph leads to several possible explanations. These include: a restriction in flow upstream; water flowing around the weir during major events; the float sticking in the stillwell near peak heights; or the result of a mild intensity storm which takes a long period of time for the entire basin to produce runoff. The latter might have only minor changes in flow after the initial flush, which the flow recorders might not respond to, till a peak is reached.

Statistical analyses were performed on flow data from Sites 1, 2, and 3 over the three year period using the ANOVA procedure to compare planed versus unplaned fields in terms of runoff (L/ha), the start time to flow and the time for flow to peak (hours). Site 4 was not used for analysis due to lack of sufficient data. Event 190789 at site 1 was not used because the recorded data are questionable due to severe flooding. Event 100490 at site 2 was also eliminated since the majority of the runoff came from the adjacent field.

With respect to the first variable, significantly more runoff occurred from the planed area in Site 3 (54,809 L/ha) when compared with the unplaned area (19,443 L/ha) ($F=7.37$; df=1,15; $P=0.0300$; n=8). Although the difference was not significant, on Site 2 the planed field also had more runoff (70,354 L/ha) when compared with the unplaned area (14,915 L/ha). Lack of significance may have been due to an insufficient number of replications or to a large variance in the values.

In contrast to both of the above, Site 1 experienced more runoff in the unplaned field as opposed to the planed field (138,116 versus 46,693 L/ha, respectively); however, due to the variability the difference was not significant.

In all cases, with respect to the starting time to flow, the unplaned fields started flowing at a later time when compared with the planed fields. No significant differences could be detected. Considering the time for flow to peak, again, no significant findings were detected at any of the sites (again probably due to lack of replications). However, in the majority of cases (both sites 2 and 3) the unplaned fields required less time to arrive at peak flow when compared with the planed fields (1.4 versus 2.4 hours and 1.5 versus 2.3 hours, respectively). Table 7 provides the runoff (L/ha) and "time to peak" (hrs) means as well as determining which field started flowing first and general comments for sites 1 to 3.

The mean runoff volumes for the planed fields were: 46,693 L/ha at site 1; 70,354 L/ha at site 2; and 54,809 L/ha at site 3. This indicates that planing is relatively consistent with regards to surface runoff.

Table 7. Means for runoff (L/ha), and time to peak (hrs) as well as the fields flow starts and general comments.

Site	Field	Runoff (L/ha)	Flow Start*	Time to Peak (hrs)	General Comments
1	planed	46,693	1st/same time	5.1	- lower flow volumes - flow started first, same time finished first - no major build-up of surface runoff in drainage furrows - no substantial field ponding
	unplaned	138,116	2nd/same time	5.2	- higher flow volumes - flow started 2nd, same time finished 2nd - frequently though weir 4 was the only weir (out of the 6) to flow - major buildup of surface runoff surrounding drainage furrows (primarily weir 4) - ponding in several areas
2	planed	70,354	varied	2.4	- higher flow volumes - field to flow 1st varied - frequently, planed field was the only one to flow - no field ponding
	unplaned	14,915	varied	1.4	- lower flow volumes - field to flow 1st varied - frequently no flow or just a trickle - some ponding areas
3	planed	54,809	varied	2.3	- higher flow volumes - field to flow 1st varied - some ponding on headlands near weir - no substantial ponding in field
	unplaned	19,443	varied	1.5	- lower flow volumes - field to flow 1st varied - several small pockets of ponding throughout the field

* Flow start: determines which field was first to record a flow measurement at the start of an event.

The runoff from the natural fields ranged from 14,915 L/ha for site 2 to 138,116 L/ha for site 1. Overall, from an agronomic aspect, land planing was an advantage since the ponding of surface water was virtually eliminated. However, observing the natural surface drainage of a field should be the first step in choosing an appropriate water and soil management system.

3.4 RUNOFF QUALITY

3.4.1 Observations

The number of samples collected and the corresponding analysis performed is recorded in Table 8. The introduction of the Isco automated samplers in the second year dramatically increased the number of samples collected at some of the sites. Low flow events however, were unable to trigger the Iscos and therefore some sites with limited precipitation saw no increase in samples collected.

The samplers, once triggered, were programmed to collect one sample every hour for a maximum of 24 samples (24 hours). Therefore, with significant runoff the action and interaction of total phosphorus (TP), filtered reactive phosphorus (FRP) and sediment (SED) could be monitored throughout an event. Figures 63 to 75 from various events, demonstrate the trends observed from start to finish of runoff occurrences for the three components. Such trends include:

- increases in sediment appear to cause increases in total phosphorus
- when sediment concentrations are low, filtered phosphorus concentrations approximate total phosphorus concentrations
- there is an early flush of sediment and phosphorus within the first two hours of an event
- a steady state is reached after the initial flush

Table 8. Samples Collected (1989-1991).

Year A-M	Site	Weir	Samples Collected	Analysis			Total Anal.
				TP	DRP	SED	
1989	1	1	6	6	5	4	15
		2	7	7	6	6	19
		3	7	7	5	6	18
		4	8	8	7	8	23
		5	8	8	7	8	23
		6	6	6	5	5	16
		Tile	2	2	2	2	6
	2	1	4	4	4	4	12
		2	4	4	4	4	12
		Tile	2	2	2	2	6
	3	1	8	8	8	8	24
		2	8	8	8	7	23
		Tile	10	10	10	10	30
	4	1	2	2	2	2	6
		2	3	3	3	3	9
		Tile	-	-	-	-	-
1990	1	1	4	4	4	4	12
		2	55	55	55	55	165
		3	2	2	2	2	6
		4	229	229	229	229	687
		5	8	8	8	8	24
		6	8	8	8	8	24
		Tile	18	18	18	18	54
	2	1	60	60	60	60	180
		2	30	30	30	30	90
		Tile	-	-	-	-	-
	3	1	27	27	27	3	81
		2	1	1	1	1	3
		Tile	1	1	1	1	3
	4	1	1	1	1	1	3
		2	1	1	1	1	3
		Tile	2	2	2	2	6

Table 8. Samples Collected (1989-1991) (concluded).

Year A-M	Site	Weir	Samples Collected	Analysis			Total Anal.
				TP	DRP	SED	
1991*	1	1	1	1	1	1	3
		2	1	1	1	1	3
		3	2	2	2	2	6
		4	95	94	94	95	283
		5	6	6	6	6	18
		6	4	4	4	4	12
		Tile	8	8	8	8	24
	2	1	-	-	-	-	-
		2	-	-	-	-	-
		Tile	-	-	-	-	-
	3	1	-	-	-	-	-
		2	-	-	-	-	-
		Tile	3	3	3	3	3
	4	1	-	-	-	-	-
		2	-	-	-	-	-
		Tile	1	1	1	1	3
Grand Total (3 Years)			653	652	645	647	1944

* third year collection ended at 31 December 1991.

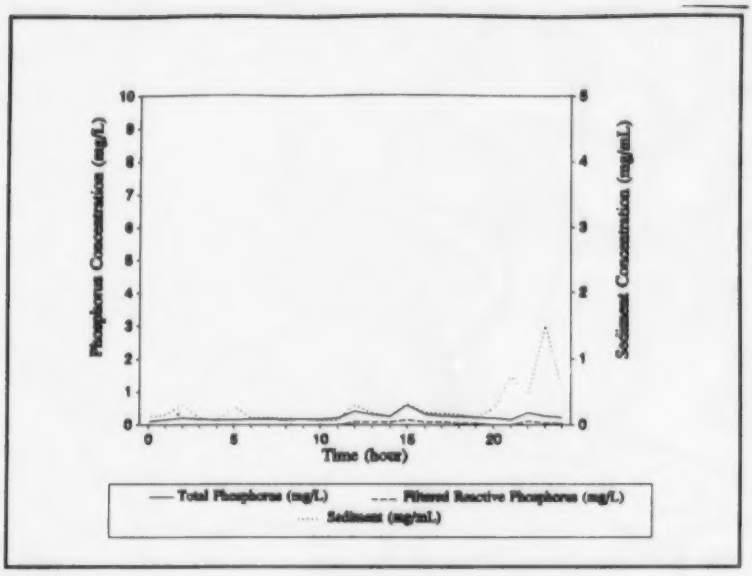

Figure 63. Site 1 Unplaned: Sed. & Phos. (May 16/90).

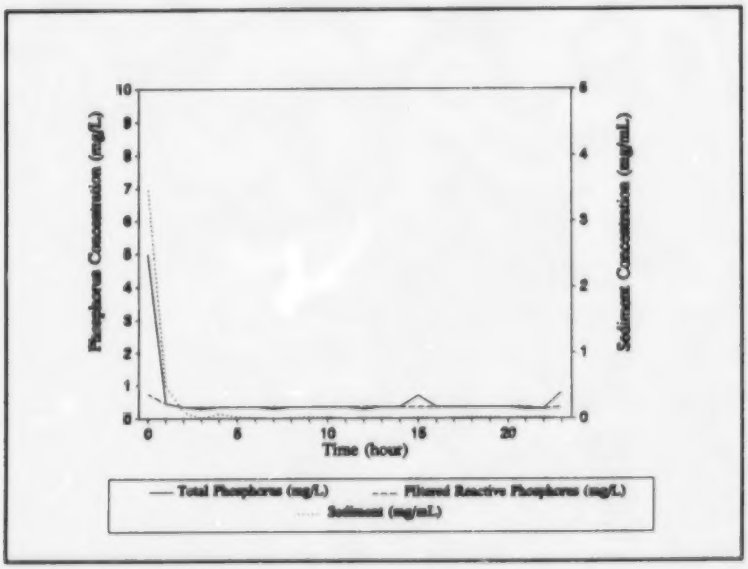

Figure 64. Site 1 Planed: Sed. & Phos. (September 14/90).

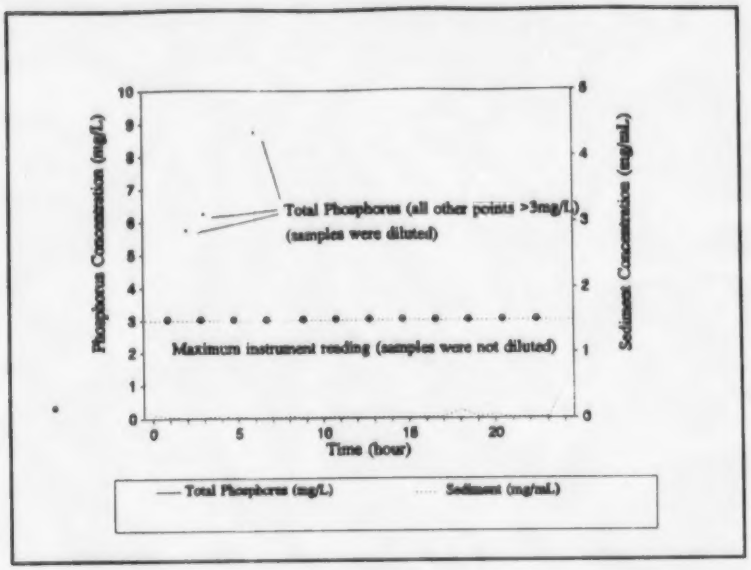

Figure 65. Site 1 Unplaned: Sed. & Phos. (September 14/90).

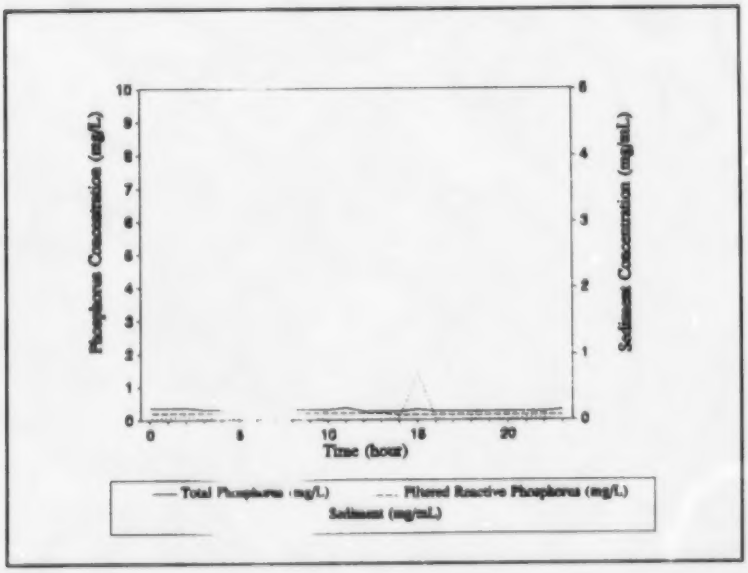

Figure 66. Site 1 Planed: Sed. & Phos. (September 16/90).

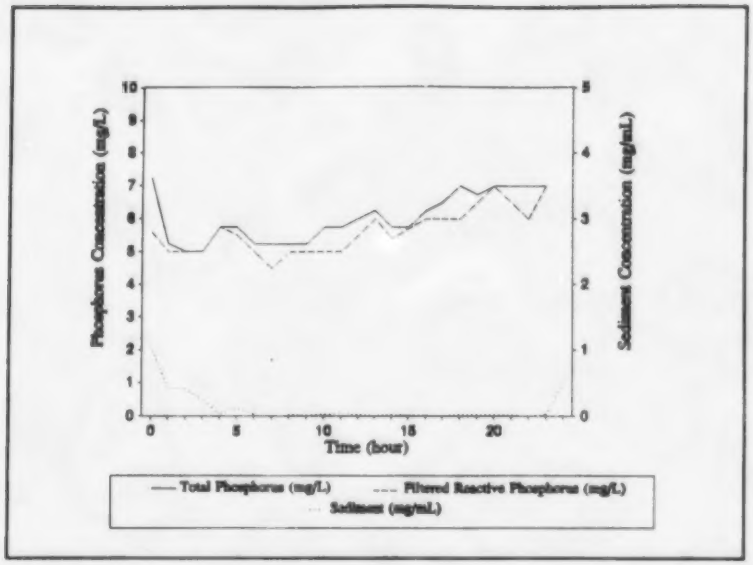

Figure 67. Site 1 Unplaned: Sed. & Phos. (September 16/90).

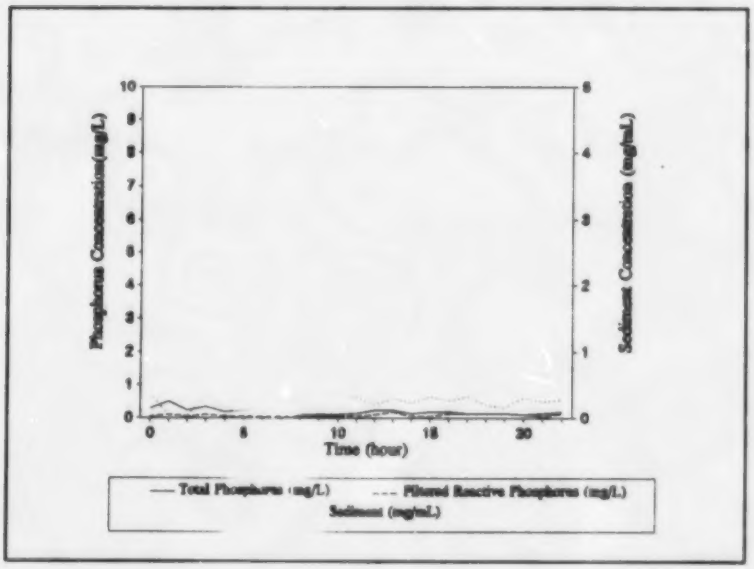

Figure 68. Site 1 Planed: Sed & Phos. (December 5/90).

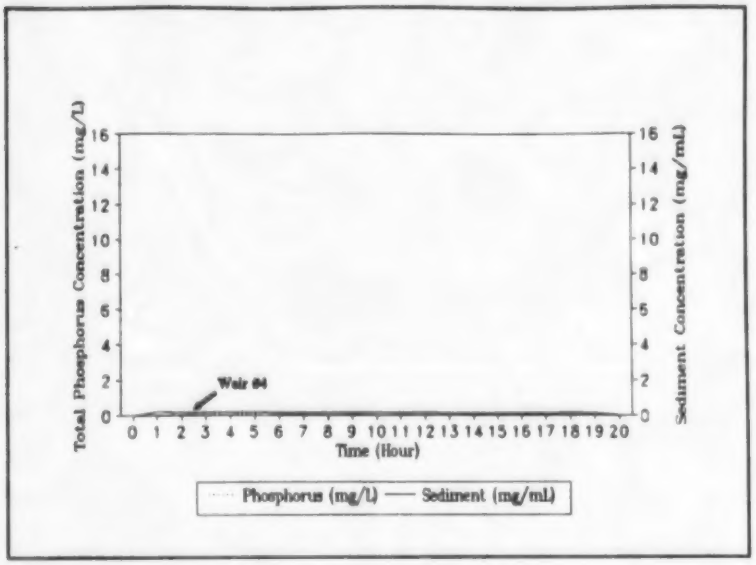

Figure 69. Site 1 Unplaned: Sed. & Phos. (February 2/91).

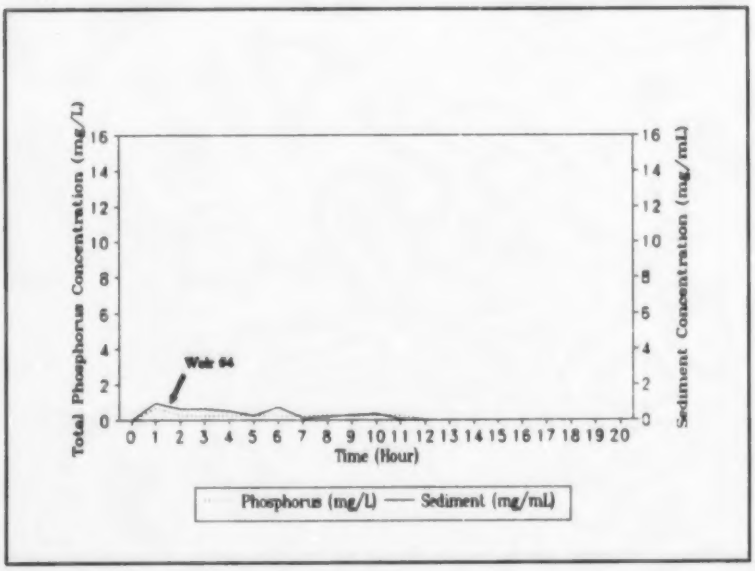

Figure 70. Site 1 Unplaned: Sed. & Phos. (April 9/91).

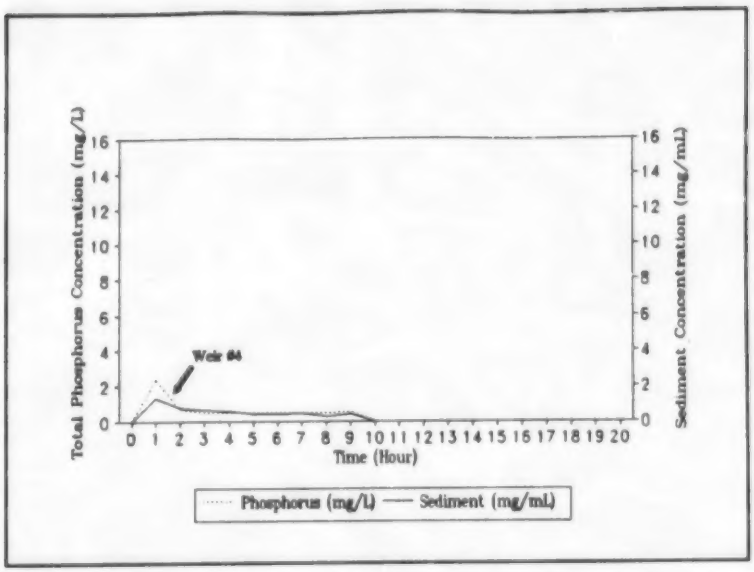

Figure 71. Site 1 Unplaned: Sed. & Phos. (April 20/91).

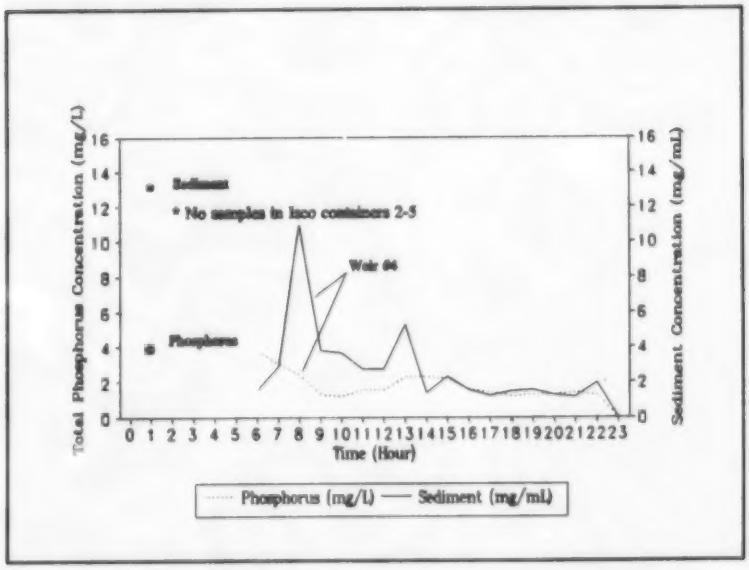

Figure 72. Site 1 Unplaned: Sed. & Phos. (May 25/91).

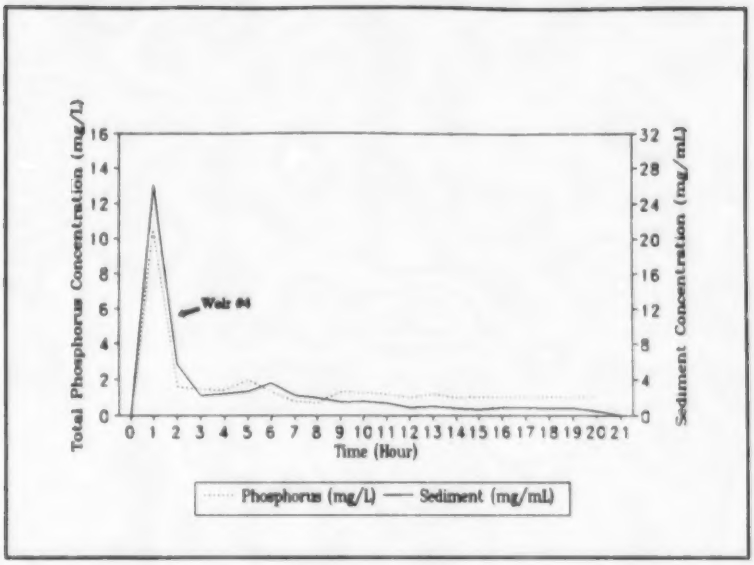

Figure 73. Site 1 Unplaned: Sed. & Phos. (June 3/91).

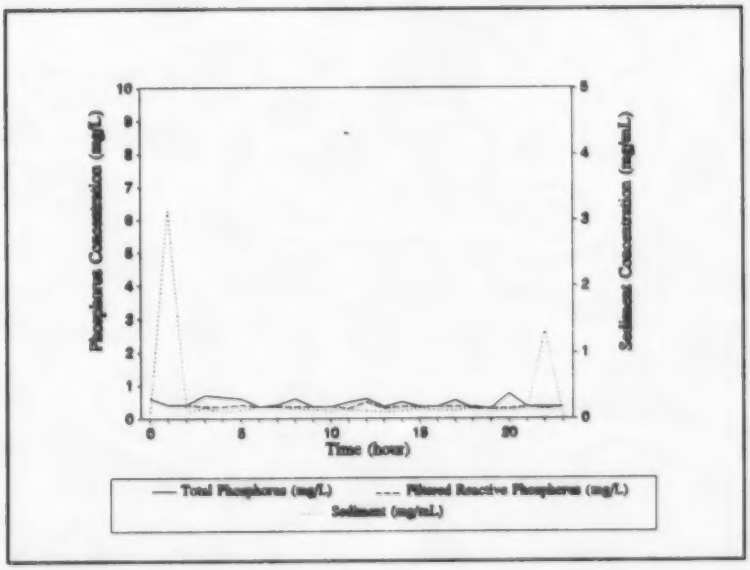

Figure 74. Site 2 Planed: Sed. & Phos. (September 14/90).

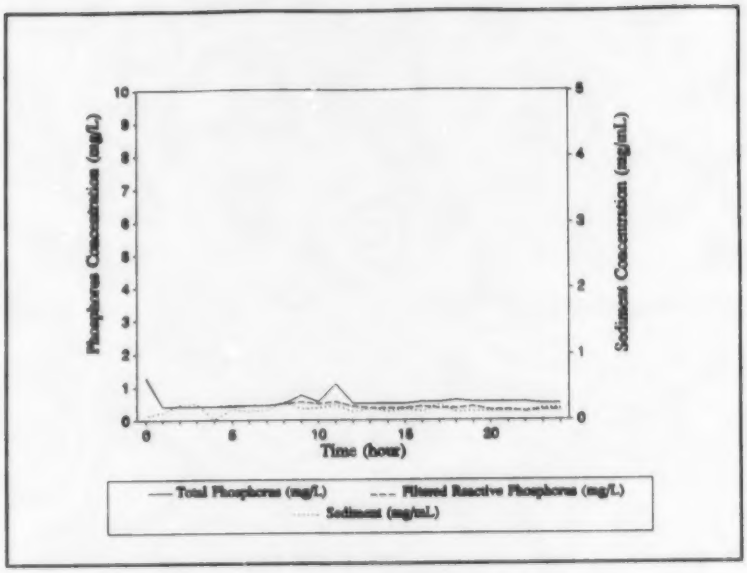

Figure 75. Site 2 Unplaned: Sed. & Phos. (September 14/90).

- the concentrations for sediment and phosphorus losses do not form a consistent response between the planed and unplaned fields
- less phosphorus and sediment loss occurs during the months when a crop canopy is in place
- concentrated manure application greatly increases phosphorus contributions to the surface runoff

3.4.2 Discussion

Mean concentrations of total phosphorus (TP), filtered reactive phosphorus (FRP) and sediment (SED) for various events at each site are shown in Tables 22, 23, 24 and 25 in the Appendix. Table 9 provides the TP, FRP and SED ranges and means for all the samples collected during the study. Samples from site 1 where TP and FRP exceeded 3.0 mg/L were not included in determining means. These excessive values were a result of an application of solid turkey manure at a rate of 22.4 tonne/ha on the planed field only.

The analyses indicated that the concentrations of phosphorus and sediment, from collected field runoff samples, may occur differently between the planed and unplaned fields yet any consistent patterns cannot be reached among the sites. The range in concentrations for TP, FRP, and SED varied substantially. Concerns about excessive phosphorus concentrations and subsequent stream loadings led to the formation of SWEEP, however only general guidelines exist (which should be supplemented by site-specific studies) to evaluate the analytical results.

The Ontario Ministry of the Environment (MOE) Water Management Guidelines states that "excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 0.03 mg/L." Higher TP concentrations would be expected from field runoff when compared to rivers, however much of the surface water in our study region appears susceptible to high phosphorus levels. Sampling reports from a yet unpublished MOE study by Dr. L. Logan shows that several of the rivers in this

Table 9. Total Phosphorus, Filtered Reactive Phosphorus and Sediment Ranges and Means for Samples Collected from 1989 to 1991.

Site	Field	Total P (mg/L)				Filtered Reactive P (mg/L)				Sediment (g/L)			
		No. of Obs.	Min.	Mean	Max.	No. of Obs.	Min.	Mean	Max.	No. of Obs.	Min.	Mean	Max.
1	planed	85	0.10	2.92	8.75	-	-	-	-	81	0.01	0.23	1.76
	*planed	34	0.10	0.66	4.25	29	0.00	0.10	0.80	-			
	unplaned	372	0.04	0.65	22.60	265	0.00	0.24	2.05	371	0.01	0.73	26.07
2	planed	64	0.10	0.46	2.70	64	0.10	0.34	2.55	64	0.01	0.23	2.40
	unplaned	34	0.25	0.51	1.73	34	0.22	0.38	0.68	34	0.04	0.62	8.00
3	planed	35	0.10	0.48	1.30	35	0.03	0.25	1.15	11	0.00	0.69	3.00
	unplaned	9	0.03	0.33	0.85	9	0.00	0.07	0.25	8	0.00	0.81	3.70
4	planed	3	0.25	0.90	1.50	1	-	0.05	-	3	0.14	1.77	4.06
	unplaned	4	0.05	0.68	1.28	4	0.13	0.15	0.18	4	0.02	1.07	3.47

* Deleting samples taken soon after manure application.

area had higher than average TP values. Examples of means taken at specific sampling points for several rivers, in two regions of southwestern Ontario, during the period from 1980 to 1990 include: Puce River, 0.232 mg/L; Belle River, 0.321 mg/L; and Big Creek, 0.324 mg/L, which are all rivers in our study area. This compares to: Avon River, 0.147 mg/L; Conestoga River, 0.161 mg/L; and the Grand River, 0.156 mg/L, which are rivers in the London to Guelph region. The high clay content, intensive row cropping and heavy use of commercial fertilizers all contribute to these high phosphorus readings.

Research by Miller (1979) examining subsurface drainage water in mineral soils in Kent County reported a TP range of 0.03 to 0.24 mg/L. This level was considered low and was not thought to lead to significant deterioration of water quality. Means from Table 9 all exceed this level. PLUARG (pollution and land use activities reference group) studies indicated that the overall total loadings of phosphorus are high in this region. Miller et al. (1982) produced a map from the PLUARG data estimating the unit-area loads of TP (six levels) from agricultural land in thirteen regions of southern Ontario. These levels ranged from a low of less than 0.20 kg/ha/yr to a midpoint of 0.80 kg/ha/yr to a high of greater than 1.40 kg/ha/yr. This map identified our study area as the region with the highest TP loading rate with estimated phosphorus loadings of 1.11 to greater than 1.40 kg/ha/year.

Our study results did not produce loadings to this extent though differences did occur between the planed and unplaned fields due to differences in the amount of surface water runoff. Greater runoff meant greater loadings of TP, FRP, and SED. Table 10 provides totals (kg/ha) of phosphorus and sediment for selected events. Some of the earlier event totals may be exaggerated if the hand collected samples were obtained during an early flush of nutrient and sediment runoff. Problems associated with winter monitoring reduced the number of runoff samples collected in the winter. Therefore the observed annual average of surface flow events (eight events) will be used in conjunction with the mean flow and the mean concentrations to estimate annual

Table 10. Total (kg/ha) Losses of Phosphorus and Sediment for Selected Events.

Site	Event D/M/Y	Field	Runoff (L/ha)	TP (kg/ha)	FRP (kg/ha)	SED (kg/ha)
1	190789	Planed	4,557,426	0.73	0.0	46
		Unplaned	2,930,549	0.47	0.0	293
	060990	Planed	463,295	2.78	2.59	32
		Unplaned	1,224,734	0.55	-	60
	310591	Planed	39,192	0.05	-	55
		Unplaned	64,266	0.08	-	111
2	190689	Planed	22,259	0.028	0.007	13
		Unplaned	5,025	0.009	0.003	21
	260689	Planed	30,706	0.16	0.01	74
		Unplaned	820	0.0	0.0	7
	260789	Planed	191,301	0.18	0.08	19
		Unplaned	54,128	0.05	0.04	43
	140990	Planed	12,541	0.007	0.005	2
		Unplaned	7,582	0.003	0.003	2
3	190689	Planed	144,756	0.15	0.03	167
		Unplaned	68,094	0.02	0.002	41
	200789	Planed	116,193	0.04	0.03	17
		Unplaned	38,668	0.006	0.005	4
	260789	Planed	126,082	0.03	0.007	7
		Unplaned	42,585	0.006	-	-
4	250589	Planed	*	-	-	-
		Unplaned	472,325	0.4	0.06	236
	210990	Planed	1,579,962	0.39	0.016	221
		Unplaned	**	-	-	-

* Recorder failure ** Weir washout

loadings (Table 11). These annual phosphorus loadings though could be exceeded in one event with a severe rainstorm or with the application of high rates of manure (particularly when it is not incorporated). As mentioned previously, the field with the greatest runoff volume (L/ha) produced the greatest loadings (kg/ha/yr) of TP, FRP, and SED. Therefore at site 1 the planed field contributed less loadings then the unplaned field but at sites 2 and 3 the planed fields produced the highest loadings of TP, FRP, and SED. Overall the estimated TP loadings from our study fields appear to be at the mid to lower end of the scale. This is based on the Miller et al (1982) P loading map and Miller's (1979) research from studies in Kent County which calculated a 0.28 kg/ha per year loading for subsurface drainage. This was considered low and non-hazardous to water quality. Coote et al (1982) estimated a TP concentration of 0.57 mg/L and a loading of 1.5 kg/ha/yr for the land planing study region. Our reported TP concentration means closely approximate the 0.57 mg/L value but the loadings estimated in our study are substantially lower than 1.5 kg/ha/yr.

The filtered reactive phosphorus concentrations appear higher and the loadings lower in our study compared to previous research estimates. Coote et al. (1982) reported soluble ortho P concentration at 0.136 mg/L and the loading at 0.36 kg/ha/yr for our study region. Table 11 shows that 5 out of 8 fields surpass this concentration (0.136 mg/L) but no fields approach the total loading estimates. Our observed flows (L/ha) from the field runoff therefore must be lower than the macro drainage basin flows (L/ha) encountered in previous studies. The FRP (representing dissolved reactive P) from our data set accounts for 47% of the total phosphorus (average of 6 fields) compared to 27% reported by Miller et al (1982).

The sediment concentration also appears higher and the loadings lower when comparing our findings to previous reports. Coote et al (1982) reported sediment at 0.36 g/L and the loadings at 961 kg/ha/yr for the planning study location. As with TP, a map identifying 13 agricultural regions' fluvial

Table 11. Mean Concentrations and Total Loadings for TP, FRP and Sediment.

Site	Field	No. of Observations*	Mean Runoff (L/ha)	TP		FRP		Sediment	
				Mean (mg/L)	Loadings (kg/ha/yr)	Mean (mg/L)	Loadings (kg/ha/yr)	Mean (g/L)	Loadings (kg/ha/yr)
1	planed	8	46,693	0.66**	0.13	0.10	0.04	0.23	86
	unplaned	8	138,116	0.65	0.72	0.24	0.27	0.73	807
2	planed	8	70,354	0.46	0.26	0.34	0.19	0.23	129
	unplaned	8	14,915	0.51	0.06	0.38	0.04	0.62	74
3	planed	8	54,809	0.48	0.21	0.25	0.11	0.69	302
	unplaned	8	19,443	0.33	0.05	0.07	0.01	0.81	126

* Observed yearly average over the three years.

** Mean TP without the manure affected samples.

sediment yields was produced from PLUARG studies. This map, produced by Wall et al. (1982), identified our study region as contributing the greatest amount of suspended sediments with a range of 475 to greater than 600 kg/ha/yr. Only the unplaned field at site 1 contributed sediment (807 kg/ha/yr) to the runoff in this range.

The interaction between total phosphorus, filtered reactive phosphorus and sediment concentrations appear to be event specific, depending on rainfall intensity, soil conditions, ground cover, etc. Examples of an early flush of sediment in an event with a corresponding increase in total phosphorus were recorded. However this initial increase in TP and SED loss only accounts for 1 or 2 samples (based on the early flush lasting 1 to 2 hours and the Isco collecting samples every hour) and therefore not enough data points exist to show significant relationship. Samples collected during the summer when less sediment is in the runoff showed FRP accounting for over 90% of the TP value.

Dividing the events into four seasons provides a comparison of phosphorus and sediment losses throughout the year. The season divisions were based on estimated canopy cover and soil conditions rather then the calender year. Spring represented fields with no cover and possible loose soil conditions due to tillage, summer has established canopy, fall has only crop residue and possible tilled soil, and winter has residue cover over frozen or thawed soil. All the values from planed and unplaned fields were combined. For site 1, a significantly higher TP ($F=11.44$; $df=2,15$; $P=0.0026$) and SED concentration ($F=14.74$; $df=2,23$; $P=0.0002$) were analyzed in the spring season runoff (Table 12). This compares to the findings by Wall et al. (1982) whose study revealed that 75% of the annual suspended sediment yield is transported in February, March and April. The lowest TP, DRP and SED concentrations were recorded in the summer season runoff. For the remaining sites, no other significant differences could be detected though the crop type did obviously alter the amount of sediment in the runoff at site 2. The tomato

Table 12. Comparison between seasons with respect to total phosphorus, dissolved reactive phosphorus and sediment content in runoff.

Site	Season	TP (mg/L)	FRP (mg/L)	SED (g/L)
1	spring	1.06a	0.17a	0.91a
	summer	0.16c	0.00b	0.08c
	winter	0.54b	0.21a	0.42b
2	spring	1.0a	0.45a	3.80a
	summer	0.71a	0.48a	0.34a
	fall	0.60a	0.25a	0.25a
	winter	0.70a	0.28a	1.11a
3	spring	0.94a	0.16a	0.30a
	summer	0.53a	0.12a	1.10a
	winter	0.41a	0.23a	0.67a
4	spring	0.97a	0.14a	-
	summer	0.15a	0.03a	-
	winter	1.10a	0.13a	-

Mean values for the same site for each variable followed by the same letter are not significantly different.
These are combined values of the planed and unplaned since no differences occurred between the fields.

crop in the first year contributed much greater sediment to the runoff then the wheat (underseeded to clover) and the soybean crops did in the following years.

3.4.3 Tile Analysis

Samples of tile flow were collected from all sites though in limited numbers. Table 13 provides analysis of tile flow at sites 1 and 2 for events where corresponding planed and unplaned samples were obtainable. Statistical analysis demonstrated greater concentrations of total phosphorus, dissolved reactive phosphorus and sediment from the runoff of the planed fields. When each site was examined separately, no significant differences could be observed between the planed versus unplaned fields at either site. For the most part, the planed areas again produced greater concentrations of total phosphorus and dissolved reactive phosphorus. Overall, sediment concentration was slightly higher on the planed fields, however, for most events the runoff showed very little difference in sediment between the planed and unplaned field.

3.5 SOILS

Detailed soil surveys of each property were conducted in the fall of 1988. Inspection sites are described in the Appendix in Tables 26 to 38 and shown on Figures 79 to 82. These investigations showed that soils within each field are relatively uniform, the main difference being attributed to micro-topographic variations and related surface drainage conditions. With good drainage, the soils throughout each field are essentially uniform.

Examinations of planed versus unplaned fields with respect to possible soil degradation, indicated a lack of impact due to the planing procedure. At all sites, topsoils were not completely removed in any locations within the field though in a few places there was evidence of topsoil removal or addition. The shallowest recorded Ap horizon at an investigation site was 12

Table 13. Tile Analysis.

Site	Event D/M/Y	Field	TP (mg/L)	FRP (mg/L)	SED (g/L)
1	140590	Planed	0.25	0.18	0.57
		Unplaned	0.05	0.08	0.02
	130890	Planed	0.65	0.60	0.07
		Unplaned	0.40	0.40	0.08
	190890	Planed	>3.0	>3.0	0.06
		Unplaned	0.35	0.30	0.04
	210890	Planed	0.70	0.65	0.04
		Unplaned	0.48	0.43	0.04
	080990	Planed	0.15	0.10	0.03
		Unplaned	0.35	0.25	0.02
	111090	Planed	0.60	0.25	0.31
		Unplaned	0.15	0.10	0.72
	261091	Planed	0.29	0.15	0.22
		Unplaned	0.54	0.07	0.37
	271091	Planed	0.56	0.09	0.25
		Unplaned	0.27	0.08	0.29
	191191	Planed	1.39	0.08	0.19
		Unplaned	1.61	0.12	0.30
2	200789	Planed	0.43	0.33	0.10
		Unplaned	0.10	0.05	0.0
	270789	Planed	0.18	0.18	0.10
		Unplaned	0.08	0.03	0.0

cm compared to an average of 25 cm on the corresponding unplaned field. Substantial removal of topsoil was not common and was limited to a couple of sites. Soil investigations revealed no apparent alteration to the soil structure due to land planing and differences in assigned compaction ratings for the planed and unplaned fields were negligible.

Composite soil samples were collected from each field, during the winter, for fertility analysis. Results for the last three years are presented in Table 14. There has been no significant change in the nutrients over the three year period. The soil organic matter levels taken at a 0-15 cm depths were similar between the fields. The ranking of phosphorus levels between the two fields at each site is also unchanged over the three years.

The heavy clay soils found in this region are capable of shrinking and swelling which contributes an unknown factor to the drainage and phosphorus loss problem. The dry summer months can lead to soil cracking, resulting in a high infiltration rate until the cracks are filled. This infiltration to the tile bed and beyond is clearly demonstrated in Table 15. In late July, the planed field at site 1 received an application of solid turkey manure (22.4 tonne/hectare). The first significant event following the application resulted in high phosphorus readings in the tile analysis. The extensive soil cracking at this time provided direct channels for the surface water to drain into the tile lines. The cracks quickly began to seal as the soil swelled which is evident with the drastically reduced phosphorus concentration in tile flow sample taken two days later. The concentration of phosphorus in the surface runoff remained high for seven weeks following the manure application.

3.6 AGRONOMIC PRACTICES/FARM MANAGEMENT

3.6.1 Cropping/Residue Management

The fall crop residue estimate and an overall cropping management factor (C-value) for each field over the three years is presented in Table 16. C-values reflect the influence of various types of crop canopy and management practices on soil erosion by water. When the C-value is multiplied

Table 14. Fertility Analysis.

Fertility (ppm)										
Site	Field	Year	P	K	Mg	Ca	Zn	Mn	pH	% O.M.
1	planed	1989	16	184	600+	5907	-	-	7.0	-
	unplaned	"	32	195	600+	5791	-	-	6.9	-
	planed	1990	18	246	820	6040	1.4	8.0	7.1	3.7
	unplaned	"	47	200	550	6580	1.0	11.6	7.8	3.7
	planed	1991	18	353	660	2782	-	-	7.1	4.2
	unplaned	"	28	345	620	3041	-	-	7.1	4.5
2	planed	1989	59	273	270	2546	-	-	6.2	-
	unplaned	"	66	271	244	2445	-	-	5.8	-
	planed	1990	44	196	359	3128	1.5	8.7	6.6	3.7
	unplaned	"	49	239	286	2936	1.7	7.7	6.4	4.1
	planed	1991	44	286	312	1963	-	-	6.7	4.5
	unplaned	"	46	323	276	1940	-	-	6.5	4.5
3	planed	1989	18	170	366	5392	-	-	5.9	-
	unplaned	"	14	160	292	2390	-	-	5.7	-
	planed	1990	26	197	348	2611	2.0	5.8	5.9	5.0
	unplaned	"	8	158	398	3302	1.1	4.0	6.4	4.2
	planed	1991	16	204	397	1797	-	-	6.4	4.1
	unplaned	"	11	166	364	1981	-	-	6.8	3.4
4	planed	1989	33	197	252	3217	-	-	6.3	-
	unplaned	"	52	198	269	4869	-	-	6.7	-
	planed	1990	29	192	321	4280	1.0	4.7	6.5	4.6
	unplaned	"	36	198	376	3980	1.6	8.6	7.0	4.7
	planed	1991	40	225	279	2378	-	-	6.6	4.6
	unplaned	"	42	233	271	2503	-	-	7.1	4.4

Table 15. Site #1 Tile Effluent Analysis After Manure Application on Planed Field Only.

Field	Date	FRP (mg/L)	TP (mg/L)	Sediment (g/L)
planed	19/08/90	>3.0	>3.0	0.06
unplaned	"	0.30	0.30	0.04
planed	21/08/90	0.65	0.70	0.04
unplaned	"	0.43	0.48	0.04
planed	08/09/90	0.10	0.16	0.03
unplaned	"	0.25	0.35	0.02

Table 16. Estimated Fall Crop Residue and Overall Average of C-values for the Three Years.

Site	Year	% Crop Residue		C-Values		Fall Tillage	
		Planed	Unplaned	Planed	Unplaned	Planed	Unplaned
1	1	75-100	75-100	0.65	0.32	winter wheat	
	2	0-15	0-15	0.27	0.27	moldboard pl.	
	3	30-45	30-45	0.40	0.40	none	
2	1	75-100	75-100	0.30	0.30	winter wheat	
	2	75-100	75-100	0.20	0.20	clover	
	3	45-60	45-60	0.32	0.32	none	
3	1	30-45	15-30	0.34	0.44	disk	moldboard pl.
	2	15-30	15-30	0.53	0.53	chisel pl.	
	3	75-100	75-100	0.30	0.30	winter wheat	
4	1	0-15	0-15	0.53	0.36	chisel pl.	
	2	45-60	0-15	0.46	0.58	wheat	V-plowed
	3	0-15	0-15	0.53	0.53	chisel pl.	

by 100, it gives a percentage value which is the amount of erosion that would occur under fallow or bare soil conditions. The lower C-value fields should have less sediment and total phosphorus loss but will not necessarily reduce dissolved phosphorus. Averaging the C-values for each site produces a site ranking as follows (least possible erosion to most possible erosion): site 2; site 1; site 3; and site 4. With the varying storm intensities it is difficult to compare this C-value ranking to the recorded phosphorus and sediment loss between sites.

The importance of the factors which determine C-values are shared by both the planed and unplaned fields. The planed field however should receive the most benefit from altering management and cropping practices to control erosion since these practices (i.e. increasing surface residue) will reduce the surface runoff velocity.

3.6.2 Yields

The crop yields for each field over the three year study are provided in Table 17. Resulting yield benefits from a planed field may be limited to year, where certain precipitation events occur during certain crop growth stages. In the first year there was a severe storm in July which caused extensive flooding. The increased yields from the planed fields indicate that continuous ponding was avoided on these fields resulting in less harm to the crop. Eliminating ponding in late summer or fall, when the crop is further developed, may not provide any yield benefits from a planed field. An intense rain storm just after planting or at crop emergence may actually cause more harm on the planed field, in some cases, due to the possible increased runoff velocity.

Statistically, no significant differences were observed between the planed and unplaned areas of the sites. Soybean yields averaged 37.8 bu/ac on the planed fields and 39.2 bu/ac on the unplaned fields. Winter wheat yields ranged from 62 to 66 bu/ac for planed and unplaned fields, respectively. There was only one replication for corn where the unplaned field yielded less than the

Table 17. Crop Yields (1989-1991).

Site	Year	Planed		Unplaned		Essex	
		Crop	Yield (bu/ac)	Crop	Yield (bu/ac)	County Avg. (bu/ac)	General Comments
1	1989	washed out	-	soybeans	17	30	- flooding in May and July
	1990	winter wheat	61	winter wheat	75	67	- cool, wet spring
	1991	soybeans	30	soybeans	33	26	- drought
2	1989	tomatoes	10.4 ton/ac	tomatoes	9.6 ton/ac	-	- frost damage
	1990	winter wheat	63	winter wheat	57	67	- cool, wet spring
	1991	soybeans	35	soybeans	27	26	- drought
3	1989	corn	200	corn	195	123	
	1990	soybeans	61	soybeans	61	39	- cool, wet spring
	1991	soybeans	29	soybeans	31	26	- drought
4	1989	soybeans	43	winter wheat	75	soy:30 ww: 60	
	1990	soy (replant)	34	soy (replant)	44	39	- cool, wet spring
	1991	winter wheat	54	soybeans	24	soy: 26, ww: 40	- drought

planed area (195 bu/ac versus 200 bu/ac). Likewise, for the tomato crop, the planed area yielded 10.4 ton/ac and the unplaned area yielded 9.6 ton/ac of tomatoes. Looking at sites separately, again, no significant differences were detected between the planed and unplaned areas in terms of crop yields (converted to a percentage number). However, site 2 consistently had greater yields in the planed fields as opposed to the unplaned fields over the three year period. This site was managed as no-till once the tomato beds were worked down and planted into winter wheat (fall 1989). The yields at site 2 were not significantly greater on the planed fields due to lack of replications.

3.7 ECONOMICS

Land reshaping is a costly procedure. The equipment alone can cost between $30,000 to $40,000 (laser and receiver: $20,000-$25,000, scraper: $10,000-$15,000). Estimated time required to complete the planing, without constructing the waterways, ranges from 5 to 10 hours per hectare. Additional costs include tractor depreciation and fuel consumption. One farmer estimated the cost to land shape at $260/hectare (not including the initial plowing or final waterways and chutes). Another farmer quoted a figure of $760/hectare (not including the accompanying waterways). This should be a "one time" cost, however, there may be situations where sections of the field would have to be re-levelled due to erosion or tillage altering the surface flow pattern.

All fields in our study were tile drained and all the cooperators recommended tile drainage indicating that it was not a case of "either-or" with surface and sub-surface drainage. The resulting yields are usually the most important economic factor when examining management systems. Yield advantages from planing (when compared to unplaned fields) tend to occur only in wet growing seasons. Therefore other factors must be involved in the decision to land plane. The farmers cited several reasons for their desire to land plane including:

- work the fields earlier in the spring
- less chance of compaction due to wet field conditions
- ponding areas create hard spots that might require extra or different tillage
- these hard spots can create uneven crop growth
- uneven crop growth creates more combine problems at harvest
- harvest delays due to wet areas are minimized
- changing cropping plans due to wet field conditions is minimized

These reasons for reshaping are all intangible items with respect to the economic benefits. Farmers should be aware that seeking increased yields to account for the cost of land planing will take a number of years. Land planing fields for more lucrative cash crops (i.e. tomatoes) would help to justify the initial costs. Studying the natural drainage of a field may offer some less expensive alternatives to land planing.

3.8 MODELLING

The CREAMS model was modified to provide continuous modelling of surface episodes of overland flow. Model predictions were found to be sensitive to the surface roughness parameter and the effective conductivity parameter. Values for the surface roughness were determined across seasons for the various crop rotations (differences in roughness between planed and unplaned were not considered). Values for effective saturated conductivity were determined for each field and each season by calibration. These values were then modelled to produce accurate model predictions. This approach resulted in correct predictions of 116 out of 130 observed episodes of overland flow (Table 18). In addition, 60 unobserved (no field record) predictions of overland flow events were made of which 22 can be accounted for by instrument failure (i.e. weir wash-outs, float freezing, cable off

Table 18. Observed and Predicted Overland Flow Episodes.

Field Application	Observed Episodes (a)	Predicted Episodes (b)	Unobserved Predictions (c)	Model Reliability*
Lanoue W1	12	12	5	0.71
Lanoue W2	11	11	3	0.78
Barrette W1	15	13	4	0.65
Barrette W2	11	10	5	0.60
Doyle W1	2	2	4	0.33
Doyle W2	12	9	4	0.46
AFF Farms W1	11	9	6	0.46
AFF Farms W2	11	10	6	0.56
AFF Farms W3	10	9	7	0.50
AFF Farms W4	15	14	5	0.69
AFF Farms W5	9	9	5	0.64
AFF Farms W6	11	8	6	0.43

Model Reliability* = 1 - (abs(a-b))/(b+c) - c/(b+c)

pulley etc.). The reason for the remaining predictions of non-events is unknown though extensive summer soil cracking may account for a few predictions where runoff did not occur.

Once predictions of event occurrences were established, modelled predictions of flow quantities were recorded for each observed overland flow event. Large discrepancies developed between the modelled and observed results. Several limits within the modified CREAMS model could create the flow volume differences (i.e. minimum field slope for CREAMS is 0.12 which exceeded the actual slopes) since the modifications for this study were not designed to provide quantity estimates.

Predictions of phosphorus transport were modelled in association with predictions of observed flow events. The concentrations of predicted and observed total and filtered reactive phosphorus at site 2, weir 1, are presented in Tables 18 and 19.

The modelling procedure was simplified through the use of an entry chart for the various parameters (Table 19). By identifying and altering the hydrological parameters that affect the occurrence of surface drainage episodes, the modelling program provides a basis for testing management strategies for phosphorus control. In one exercise the basin size was divided in half while the other parameters remained the same. The total runoff was half the original, since the model directly correlates flow volume with area, but the peak flow was reduced more than 50%. This may indicate that the smaller basins will have less erosive capabilities associated with high peak flows. Altering other aspects such as surface roughness and infiltration rates will also affect flow patterns. Any further modifications though should allow for more inputs regarding agronomic practices which could help the farmer in choosing a water management approach that is cost effective and environmentally friendly. The modified CREAMS program and data files accompanies this report.

Table 19. Predicted and Observed Total Phosphorus Production.

Date (Year)	Predicted Total Phosphorus Concentration (mg/L)	Observed Total Phosphorus Concentration (mg/L)
120689	0.29	not available
190689	0.32	not available
260689	0.29	not available
190789	0.29	not available
200789	0.35	1.3
260789	0.29	0.85
280889	0.31	not available
090490	0.29	not available
200490	0.29	not available
160590	0.29	not available
060990	0.32	0.53
140990	0.33	0.56

Table 20. Predicted and Observed Dissolved Phosphorus Production.

Date (Year)	Predicted Dissolved Phosphorus Concentration (mg/L)	Observed Filtered Reactive Phosphorus Concentration (mg/L)
120689	0.29	not available
190789	0.32	not available
260689	0.29	not available
190789	0.29	not available
200789	0.35	not available
260789	0.29	0.40
280789	0.31	not available
090490	0.29	not available
200490	0.29	not available
160590	0.29	not available
060990	0.32	0.47
140990	0.33	0.56

Table 21. Modelling Program Entry Sheet.

Start Date			
End Date			
Area (ha)			
Slope (%)			
Slope length (m)			
Effective Saturated Conductivity (mm/hr)			
Effective Capillary Tension (cm)			
Porosity (%)			
Plant Available Water at Field Capacity (%)			
Immobile Soil Water (%)			
Plant Water at Start (%)			
Surface Soil Depth (cm)			
Root Zone Depth (cm)			
Crop Type and Tillage Management			
Temperature			
Radians			
Modelled			
Observed			
(1) Modify and Display (2) Save the File (3) Recall a File (4) Application Files (x) Exit Command >			

A separate report was completed by Andrew Marshall from the University of Guelph, in association with Can-Ag, which detailed the set-up and calibration of the CREAMS model. This report entitled "Land Reshaping of Lowland Clay Soils: Final Modelling Report" was presented to the TED committee under separate cover.

4. SUMMARY

The two primary objectives of SWEEP are to reduce phosphorus loadings of the Lake Erie basin from cropland runoff and to improve the productivity of southwestern Ontario agriculture by reducing soil erosion that contributes to water pollution. The Land Reshaping Study involved the construction and monitoring of control structures at surface field outlets to estimate the phosphorus and sediment movement rates from cropped areas under planed and unplaned field water management practices. Four sites were involved, three in Essex county and one in Kent county, each with a planed and an unplaned field worked under similar agronomic practices. The field sizes ranged from 4 to 46 hectares though the actual drainage basins ranged from 2.6 to 20 hectares. This does not include the first year at site 2 where tomato beds were sectioned off to create one hectare basins for each field. At sites 2, 3 and 4 the monitoring stations (control structures) were set up on each field at the main surface outlet. The farmer at site 1 had divided both fields into smaller sections through the use of drainage furrows which lead to rock chute outlets at a central grass waterway. Three stations were constructed on each field at the rock chutes. This provided a total of 12 monitoring stations. Each station had a v-notch weir and a Richard's type flow recorder, as well, in the second and third year, six of the weirs had an Isco automated sampler installed by the weir. Initially all the sampling was completed manually which limited the numbers of samples that could be collected for each runoff event. The Isco is activated by a surface flow sensor and is capable of collecting up to 24 sequential samples.

Flow data and samples were collected from the monitoring stations (control structures) from April 1989 to November 1991 for as many surface runoff events as possible. Complete paired data were collected for 12 events. Partial data (i.e. only flow volumes, only samples, or data missing from one field of the pair) were recorded for 39 events. A total of 51 events occurred for which either total or partial data were recorded. This is estimated

to be 53% of the actual events that occurred at all sites over the monitoring period. The corresponding analysis along with soil and crop information defined several trends and provided several conclusions regarding the comparison of planed and unplaned fields though substantial variability existed. Statistical analysis followed using the analysis of variance procedure (ANOVA) to determine if there were measurable differences between the planed and unplaned fields for selected parameters. The Duncan's Multiple Range Test (DMRT) was also used where required to separate the means for statistical comparisons. The resulting statistics and associated discussions determined whether the observed trends were significant and helped to provide answers to the null hypotheses identified in the experimental design.

With regards to soil conditions (i.e. fertility, organic matter, structure, and compaction), examinations of planed versus unplaned fields indicated a lack of impact from planing. At all the sites, topsoils were not completely removed in any locations though in a few places there was evidence of topsoil removal or addition. The shallowest recorded Ap horizon at an investigation site was 12 cm compared to an average of 25 cm on the paired unplaned field. Substantial removal of topsoil such as this was not common and was limited to a couple of sites. The soil organic matter levels taken at a 0-15 cm depth were similar between the fields within the pairs and phosphorus ranges did not vary substantially over the three years. Soil investigations revealed no apparent alteration to the soil structure due to land planing and differences in assigned compaction ratings for the planed and unplaned fields were negligible. Therefore, as long as the farmer is cautious in the depth of cuts, soil conditions in planed fields do not change following planing.

The recorded flow data indicated increased surface runoff from the planed field in two out of the three well documented sites (sites 2 and 3). At site 1 more runoff was experienced from the unplaned field. The contrasting results appear to be related to drainage basin size and natural drainage patterns. The runoff means (L/ha) between the planed fields at sites 1, 2, and 3

(4 was not analyzed due to lack of data points) were relatively similar, ranging from: 46,693 (L/ha) for site 1; 70,354 (L/ha) for site 2; and 54,809 (L/ha) for site 3. This indicates that planing produces relatively consistent runoff volumes among sites with similar agronomic conditions. The runoff from the unplaned fields varied considerably. Calculated runoff means (L/ha) for these fields were: 138,116 (L/ha) for site 1; 14,915 (L/ha) for site 2; and 19,443 (L/ha) for site 3. The large runoff volume from the unplaned field at site 1 indicates that the natural surface drainage pattern here is prone to high runoff. In this situation planing to create smaller drainage basin, each with separate outflows should reduce the runoff volume. Therefore the lower runoff on the planed field at site 1 may be attributed to the smaller drainage basins (2.8 hectares). This reduction in flow with smaller basins may be due to a reduced slope length resulting in less accumulation of surface water which in turn prevents a lowering of the infiltration rate (due to surface soil saturation).

Fields with natural topography that are not prone to high runoff, due to depressional areas where the surface water collects, will produce a greater amount of runoff if planed. In the first year of the study equal basins were created (1 hectare) at site 2 by berming several rows of tomato beds on both the planed and unplaned fields. The runoff volume results from these equal area basins indicate much greater flow from the planed field. The planing procedure does meet the primary goal of the farmers which is to reduce the accumulation of excess surface water.

The erosion characteristics of the planed and unplaned fields in regards to phosphorus and sediment concentrations in surface runoff is still not clearly defined. The total phosphorus concentration in the runoff was greater on the unplaned at site 1 and less on the unplaned fields at sites 1, 3, and 4. Dissolved reactive phosphorus content was greater in the runoff from the unplaned fields at sites 1 and 2 and less from the unplaned field at site 3. The sediment was greater in the runoff from the unplaned areas at sites 1, 2, and 3. Less sediment would be expected in the runoff from the unplaned fields due to

ponding (which allows the sediment to settle out) and to a possible reduction in runoff velocity (resulting from a non uniform slope). These contrasting results might indicate that the phosphorus and sediment contributions to the runoff are event specific. Rainfall intensity could determine the number of micro-water sheds that are triggered to produce runoff within the drainage basin indicating that variation may occur in runoff pattern within a planed and unplaned field for each event.

The total loadings (kg/ha/yr) were estimated for sites 1, 2, and 3 based on: an average of 8 runoff events per year; concentration means for TP, FRP and SED; and runoff volume means. The planed fields on two out of the three documented sites produced more runoff and therefore contributed more phosphorus and sediment to the drainage channels. However, in our study increased runoff produced increased loadings of phosphorus and sediment and therefore, as in site 1, the greatest phosphorus and sediment losses will not always be associated with planed fields.

The interaction of total phosphorus, filtered reactive phosphorus and sediment appear to be event specific, depending on rainfall intensity, soil conditions, ground cover etc. Examples of an early flush of sediment in an event with a corresponding increase in total phosphorus were recorded. During events of low sediment loss the filtered reactive phosphorus approximated the total phosphorus value.

An established crop providing ground cover during the growing season significantly reduced the phosphorus and sediment loss to surface runoff. No differences could be detected between the planed and unplaned field with respect to season and ground cover and therefore the two fields were regarded as a single unit in the seasonal loss calculations. Therefore tillage practices and resultant residues did not affect runoff characteristics differently on planed versus unplaned fields.

The cost of the planing procedure is high and the benefits to yields (no reported significance in yields) predominately only occur in wet

seasons yet the farmers in the study report other positive intangibles. Earlier on the fields with less concern of causing compaction, elimination of water ponding areas, uniform soil moisture providing a uniform crop, and harvesting at the opportune time, are several of the benefits the farmers seek when they reshape their fields. The estimated cost though of $260/ha to $790/ha for the above mentioned benefits would deter most farmers from the planing procedure. However, protecting against crop damage, due to ponding, for more lucrative cash crops (i.e. tomatoes) could justify the initial costs of land planing.

The modelling component of the study provided a prediction of whether or not a runoff event will occur but further modification to the model is necessary to produce accurate assessments of runoff volume and phosphorus volumes. Altering various components though, will create changes in the flow pattern (i.e. peak flow rate) which can determine erosive capabilities of the runoff. Any additional modification should also include increased emphasis on the farm management practices and their relationship to runoff and phosphorus and sediment transport.

Improving the productivity of agriculture has always been an objective of the Ontario farmer. Achieving this productivity by reducing soil erosion, leading to long term sustainability has been an objective for the majority of farmers for the past several years. Nutrient and sediment loss not only impact on the environment but they contribute to economic losses as well. The annual cropland soil erosion costs in Ontario are estimated to be $68 million from yield reduction and nutrient-pesticide losses.

Observing the natural drainage pattern of a field should be the first step in choosing an appropriate water management system. Fields with high runoff to adjacent waterways may decrease the amount of flow, TP, FRP, and SED loadings if land planing is properly implemented. Fields with natural depressions holding back surface runoff will experience an increase in the

amount of surface runoff and subsequent TP, FRP, and SED loadings if planed. In the later situation an alternative to land planing should be chosen.

Therefore farmers seeking to improve their management of cropland surface water must be aware of the possible resulting environmental effects as well as initial costs and subsequent returns of implementing any new approach.

Several recommendations follow for farmers who have reshaped their land and for farmers considering developing a water management strategy as well as recommendations for future research in this area.

5. RECOMMENDATIONS

The initial computer software program to calculate the elevations into the "cut and fill" requirements was designed for irrigation systems of the southern United States. The water entering the field could be controlled and therefore only one point of entry was required per field. When this program was used for the reverse, to drain a field, the long uniform slope would cause a build-up of runoff at the single outflow point. Reducing the drainage area per outflow eliminates the extensive runoff build-up and the erosive properties associated with it. Therefore, for farmers who have planed fields or have decided to plane we recommend sectioning a field into smaller basins or land planing a field in different slope directions (to best fit the natural surface elevation) eliminating the need for a uniform slope across the entire field. The long uniform slope can require more extensive "cut and fill" alterations as well as a greater slope (steepness and length) to achieve the proper drainage. Based on our observations, basin size (drainage area with one outlet) should be restricted to a range of 2 to 5 hectares (depending on field size). Grass waterways and properly designed outflow points should be constructed to adequately handle the increased surface runoff. Outflow points should be stabilized with grass or rocks since extensive erosion can occur with the runoff volumes and velocity.

A cover crop should be established following late summer planing (drier soil reduces compaction) to protect the soil surface since the top 10 cm will have a loose and unstable structure which is prone to erosion. The cover crop will also provide root action to aid in the elimination of surface compaction.

However, for farmers who have not yet adapted the land planing practice we would recommend that they observe the natural drainage pattern of the field to determine if a less expensive and possibly less environmentally detrimental alternative is more appropriate. Alternatives such as standpipe surface inlets (i.e. Hickenbottom inlets) and sediment traps have increased in some regions of southwestern Ontario after gaining popularity in areas of the

United States where terracing was once common. Alternatives may not provide all the intangible benefits associated with land planing but provides an affordable method of reducing standing surface water without excessive nutrient and sediment loss.

Monitoring small basins (field scale) to gather necessary data concerning surface and subsurface runoff volumes and nutrient and sediment losses is an important element in erosion research. We recommend our experimental design for cost restrictive studies. However, attention to downstream flow prior to installation and providing adequate drop-off below the V-notch outlet would reduce the chance of flow back-ups at the weir, which were experienced at some sites. Float gauges to record maximum water level were installed at two sites susceptible to ditch back-ups. This gave an indication of which event recordings may have been error due to ditch back-ups but did nothing to help correct data. The inexpensive Can-Ag designed samplers collected one or two samples per event (depending on flow height) but phosphorus and sediment concentrations tended to be above average since this samples would represent an early flush. In situations where budget is not a concern, more permanent or stable control structure would improve data collection. This would reduce erosion of the structure and reduce sediment build-up at the stillwells. Replacing the stillwell and flow gauge with a data logger and pressure transducer would increase the cost but reduces the amount of time required to handle the data.

Increasing the number of monitoring sites for this study would have generated more data and therefore could have provided more statistical analysis but at a substantial increase in costs. Limiting the water quantity/quality monitoring to one site with the remaining three sites used for soils and agronomic data collection only, would be a cost effective alternative to our monitoring design. However the consistencies and inconsistencies between sites, with regards to the monitored parameters, would have been lost.

Similar field monitoring should be initiated to provide data to calibrate computer models and document other water management approaches which will aid the farmer in determining the agronomic practices best suited for his region, natural drainage patterns and soil type considering both economic returns and environmental impact.

6. REFERENCES

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7. APPENDIX

BASIN CHARACTERIZATION MAPS
(pages 106-108)

SEDIMENT AND PHOSPHORUS CONCENTRATIONS
(pages 109-112)

SOIL DESCRIPTIONS
(pages 113-138)

Figure 76. Basin characterization: Drainage pattern if no surface drains were implemented (unplaned field site 1).

* different patterns represent different micro-watersheds.

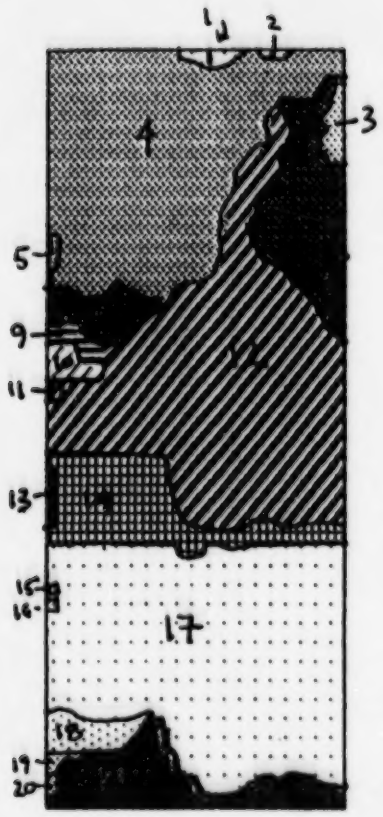

Figure 77. Basin characterization: Twenty-one watersheds in total with surface drains for unplaned field, site 1.

* different patterns represent different micro-water sheds.

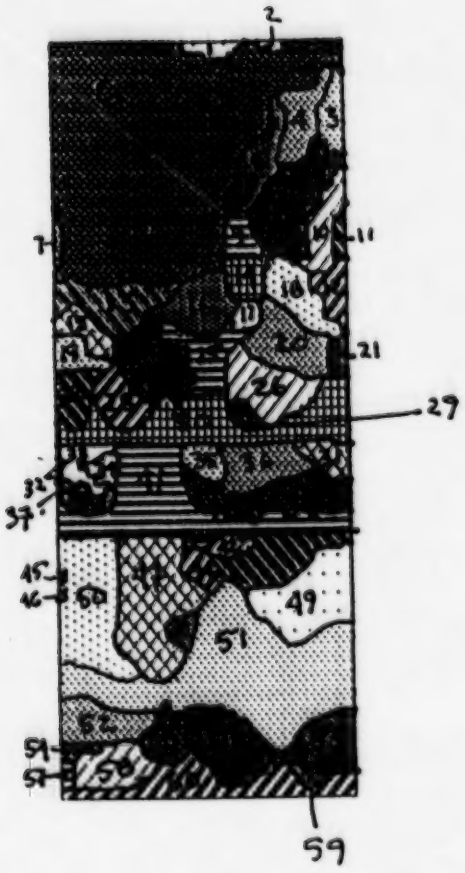

Figure 78. Basin characterization: Sixty watersheds in total with surface drains.

* different patterns represent different micro-watersheds.

Table 22. Site 1 Sediment and Phosphorus Concentrations for Paired Field Events.

Sampling Date* D/M/Y	Season**	Field	TP*** (mg/L)	FRP*** (mg/L)	SED*** (g/L)
310589	1	Planed	0.75	0.07	0.42
		Unplaned	1.31	0.27	0.68
020689	1	Planed	0.41	0.09	0.20
		Unplaned	1.29	0.24	1.05
220789	2	Planed	0.16	0.00	0.01
		Unplaned	0.16	0.00	0.10
040190	4	Planed	0.83	0.20	0.68
		Unplaned	0.58	0.25	0.35
180190	4	Planed	0.29	0.15	0.35
		Unplaned	0.76	0.33	0.59
060290	4	Planed	0.26	0.06	0.19
		Unplaned	0.62	0.33	0.31
190890	2	Planed	>3.0 ***	>3.0	0.07
		Unplaned	0.32	0.29	0.05
080990	2	Planed	>3.0 ***	>3.0	0.14
		Unplaned	0.45	-	0.05
140990	2	Planed	>3.0 ***	>3.0	0.03
		Unplaned	0.57	0.37	0.18
160990	2	Planed	6.00	5.60	0.14
		Unplaned	0.28	0.17	0.05
020691	1	Planed	1.30	-	1.40
		Unplaned	1.28	-	1.73
211191	4	Planed	0.57	0.16	0.44
		Unplaned	0.43	0.21	0.48

* Sampling date, in same cases, is one or two days after the event date (start of event).
** 1=spring, 2=summer, 3=fall and 4=winter.
*** Mean values of all collected samples for the event.
**** Several >3.0 mg/L samples were diluted resulting in values ranging from 5 to 10 mg/L.

Table 23. Site 2 Sediment and Phosphorus Concentrations for Paired Field Events.

Sampling Date* D/M/Y	Season**	Weir****	TP*** (mg/L)	FRP*** (mg/L)	SED*** (g/L)
020689	1	1	1.28	0.33	0.60
		2	1.73	0.68	4.20
030689	1	1	0.55	0.35	2.40
		2	0.45	0.43	8.00
270789	2	1	0.95	0.40	0.10
		2	0.85	0.73	0.80
220290	4	1	0.60	0.20	1.28
		2	0.80	0.35	0.93
140990	2	1	0.56	0.43	0.16
		2	0.46	0.36	0.31
111090	3	1	0.55	0.15	0.45
		2	0.65	0.35	0.05

* Sampling date, in same cases, is one or two days after the event date (start of event).
** 1=spring, 2=summer, 3=fall and 4=winter.
*** Mean values of all collected samples for the event.
**** Weir 1: planed field, Weir 2: unplaned field.

Table 24. Site 3 Sediment and Phosphorus Concentrations for Paired Field Events.

Sampling Date* D/M/Y	Season**	Weir****	TP*** (mg/L)	FRP*** (mg/L)	SED*** (g/L)
030689	1	1	1.13	0.28	0.30
		2	0.75	0.03	-
190689	2	1	1.08	0.23	1.20
		2	0.38	0.03	0.60
230689	2	1	1.05	0.18	3.00
		2	0.85	0.05	3.70
200789	2	1	0.37	0.23	0.15
		2	0.19	0.14	0.10
260789	2	1	0.23	0.05	0.05
		2	0.09	0.02	0.00
220290	4	1	0.83	0.68	0.30
		2	0.38	0.10	1.04
291290	4	1	0.33	0.17	-
		2	0.10	0.00	-

* Sampling date, in same cases, is one or two days after the event date (start of event).
** 1=spring, 2=summer, 3=fall and 4=winter.
*** Mean values of all collected samples for the event.
**** Weir 1: planed field, Weir 2: unplaned field.

Table 25. Site 4 Sediment and Phosphorus Concentrations for Selected Events.

Sampling Date* D/M/Y	Season**	Weir****	TP*** (mg/L)	FRP*** (mg/L)	SED*** (g/L)
260589	1	1	-	-	-
		2	0.85	0.13	0.50
310589	1	1	-	-	-
		2	0.55	0.18	0.50
020689	1	1	1.50	0.10	1.10
		2	-	-	-
220290	4	1	0.93	0.10	4.06
		2	1.28	0.15	3.47
200990	2	1	0.25	0.01	0.14
		2	0.05	0.05	0.02

* Sampling date, in same cases, is one or two days after the event date (start of event).
** 1=spring, 2=summer, 3=fall and 4=winter.
*** Mean values of all collected samples for the event.
**** Weir 1: planed field, Weir 2: unplaned field.

SOIL DESCRIPTIONS

Site #1: AFF Farms.

Toledo Series
Orthic Humic Gleysol
Lacustrine
Unlevelled land
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 15	Very dark gray (10YR 3/1m); clay; granular; friable; 12 to 18 cm thick; many fine random discontinuous planar voids; many medium random continuous tubular voids.
Ap2	15 - 25	Very dark gray (10YR 3/1m); clay; strong medium to coarse angular blocky; firm; 10 to 20 cm, thick; common fine random discontinuous planar voids; few fine random discontinuous tubular voids.
Bg	25 - 60	Gray (5Y 5/1m); mottled (10YR 5/6m); clay; subangular blocky; firm; 30 to 40 cm thick; many fine random discontinuous planar voids; few fine random discontinuous tubular voids.
BCg	60-100	Gray (2.4Y 5/0m); mottled (10YR 5/6m); clay; weak medium subangular blocky; very firm; 30+ cm thick.

Comments

On the average there is moderate compaction in Ap2, and upper Bg horizons. In places there is a 5 cm AB horizon, and the Ckg horizon begins at 100 cm at some sites.

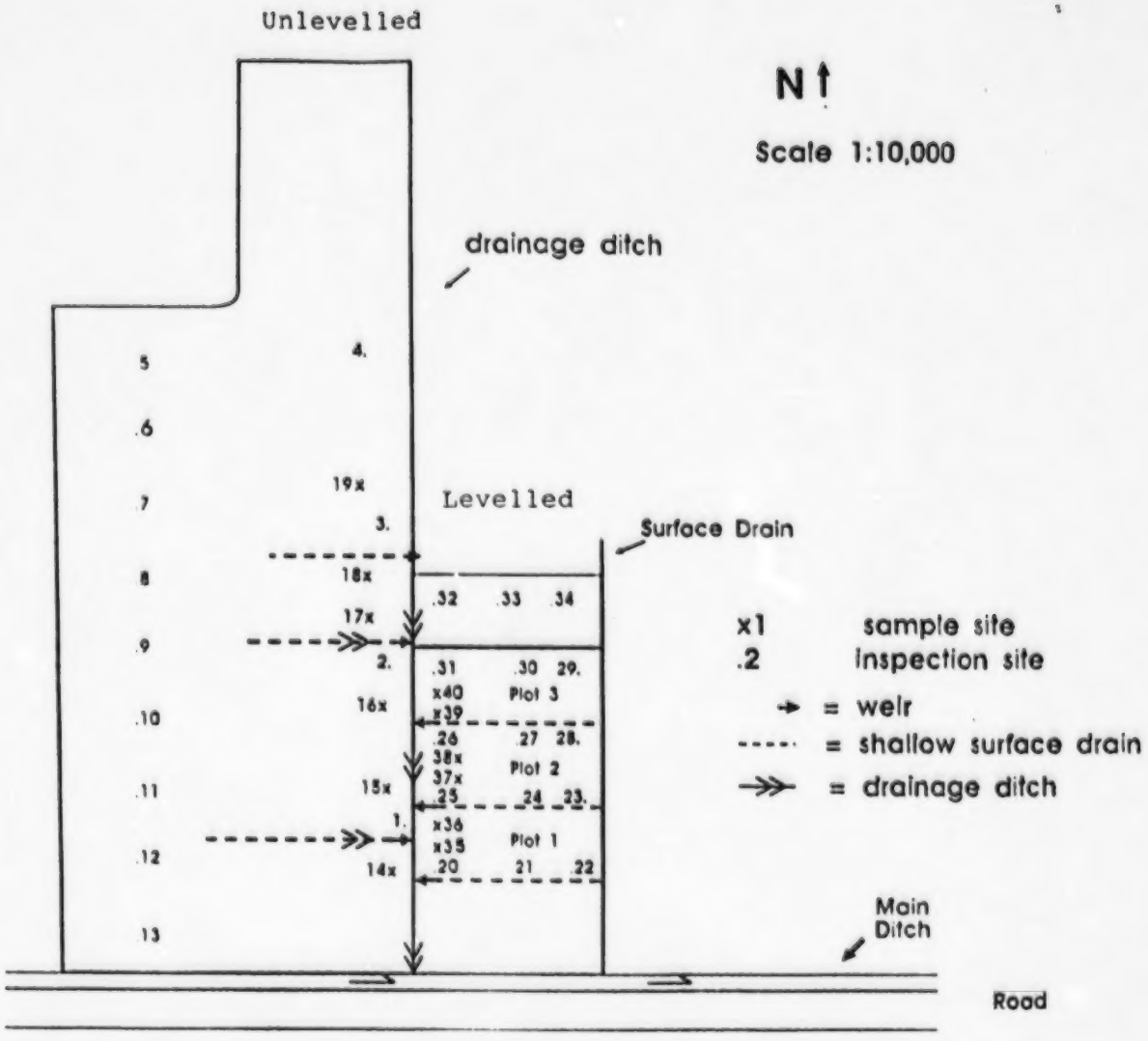

Figure 76. Field layout and soil investigation sites, AFF Farms Ltd.

Table 26. Soil site inspection summary, unlevelled field, AFF Farms.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
1	Ap1	0 - 15	
	Ap2	15 - 25	slight
2	Ap1	0 - 12	
	Ap2	12 - 25	moderate
3	Ap1	0 - 15	
	Ap2	15 - 30	moderate
4	Ap1	0 - 13	
	Ap2	13 - 25	slight
5	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
6	Ap1	0 - 12	
	Ap2	12 - 20	slight (sandy loam B)
7	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
8	Ap1	0 - 14	
	Ap2	14 - 28	slight to moderate
9	Ap1	0 - 15	
	Ap2	15 - 30	moderate
10	Ap1	0 - 14	
	Ap2	14 - 26	moderate
11	Ap1	0 - 15	
	Ap2	15 - 22	moderate
12	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
13	Ap1	0 - 14	
	Ap2	14 - 30	slight to moderate
14	Ap1	0 - 15	
	Ap2	15 - 35	moderate
15	Ap1	0 - 15	
	Ap2	15 - 31	slight to moderate
16	Ap1	0 - 18	
	Ap2	18 - 30	slight to moderate
17	Ap1	0 - 15	
	Ap2	15 - 25	moderate to severe at 15 to 30 cm
18	Ap1	0 - 10	
	Ap2	10 - 26	moderate at 10 to 33 cm
19	Ap1	0 - 15	
	Ap2	15 - 26	moderate to severe at 15 to 30 cm

Site #1: AFF Farms.

Toledo Series
Orthic Humic Gleysol
Lacustrine
Levelled land, in 1988
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 12	Very dark gray (10YR 3/1m); clay; granular; friable; 10 to 20 cm thick; many fine random discontinuous planar voids; many fine random continuous tubular voids.
Ap2	12 - 25	Dark gray (10YR 4/1m); clay; subangular block; firm; 5 to 15 cm thick; common fine random discontinuous planar voids; common fine random discontinuous tubular voids.
Bg	25 - 60	Gray (5Y 5/1m); mottled (10YR 5/l6m); clay; subangular blocky; firm; 30 to 45 cm thick; many fine random discontinuous planar voids; common very fine or fine random discontinuous tubular voids.
BCg	60-100	Gray (2.5Y 5/0m); mottled (7.5YR 4/4, 10YR 5/6m); clay; massive; very firm; 30+ cm thick.

Comments

There is slight to moderate compaction in the Ap2 and upper Bg horizons. In a few places there is evidence of topsoil removal or addition, due to effects of levelling, however, there is no apparent detrimental effect on soil quality in general.

Table 27. Soil site inspection summary, levelled field, AFF Farms.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
20	Ap1	0 - 12	
	Ap2	12 - 25	slight
21	Ap1	0 - 14	
	Ap2	14 - 18	slight
22	Ap	0 - 10	slight (some topsoil removed)
23	Ap1	0 - 12	
	Ap2	12 - 18	moderate (some topsoil removed)
24	Ap1	0 - 15	
	Ap2	15 - 30	slight
25	Ap1	0 - 15	
	Ap2	15 - 30	moderate
26	Ap1	0 - 12	
	Ap2	12 - 25	moderate
27	Ap1	0 - 15	
	Ap2	15 - 32	moderate
28	Ap1	0 - 15	
	Ap2	15 - 31	moderate
29	Ap1	0 - 15	
	Ap2	15 - 30	moderate
30	Ap1	0 - 12	
	Ap2	12 - 25	slight to moderate
31	Ap1	0 - 12	
	Ap2	12 - 25	moderate
32	Ap1	0 - 10	
	Ap2	10 - 22	moderate
33	Ap1	0 - 12	
	Ap2	12 - 25	moderate
34	Ap1	0 - 13	
	Ap2	13 - 23	moderate
35	Ap1	0 - 10	
	Ap2	10 - 26	slight
36	Ap1	0 - 13	
	Ap2	13 - 24	slight
37	Ap1	0 - 12	
	Ap2	12 - 25	slight
38	Ap1	0 - 11	
	Ap2	11 - 26	slight
39	Ap1	0 - 13	
	Ap2	13 - 26	moderate
40	Ap1	0 - 13	
	Ap2	13 - 26	slight

Site #2: Lanoue

Brookston Series
Orthic Humic Gleysol
Till
Levelled land, in 1986
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 9	Very dark grayish brown (10YR 3/2m); clay loam; granular; very friable; 9 to 15 cm thick; many fine random discontinuous planar voids; many fine random discontinuous tubular voids.
Ap2	9 - 15	Dark grayish brown (10YR 4/2m); clay loam; strong medium subangular blocky; firm; 6 to 18 cm thick; many fine discontinuous planar voids; common medium random continuous tubular voids.
Bg1	15 - 24	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; strong medium subangular blocky; firm; 0 to 10 cm thick; many fine discontinuous planar voids; common medium random continuous tubular voids.
Bg2	24 - 65	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; subangular blocky; firm; 34 to 40 cm thick; many fine random discontinuous planar voids; common fine random discontinuous tubular voids.
BCg	65-100	Gray (5YR 5/1m); mottled (10YR 5/6m); clay loam; weak subangular blocky, very firm; 35+ cm thick.

Comments

Slight compaction in Ap2 and Bg1 horizons.

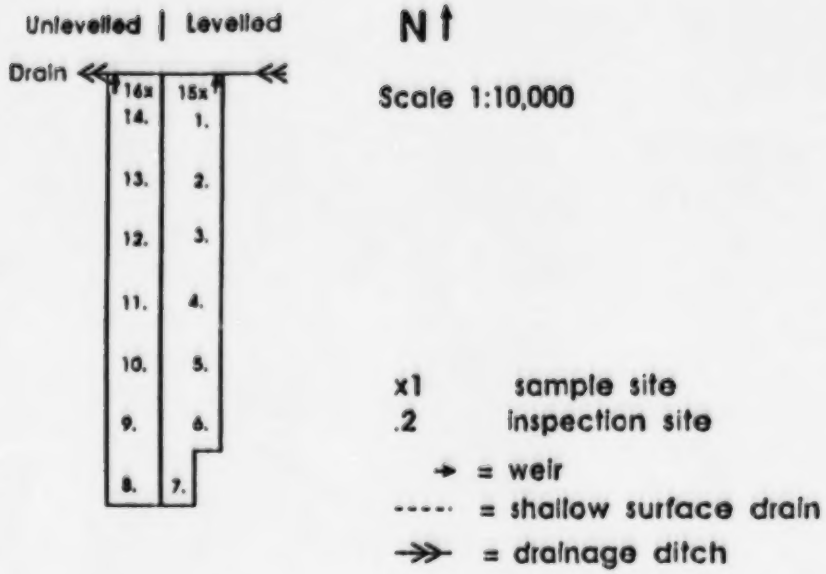

Figure 77. Field Layout and Soil Investigation Sites, Lanoue.

Table 28. Soil site inspection summary, levelled field, Lanoue.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
1	Ap1	0 - 12	
	Ap2	12 - 20	slight
2	Ap1	0 - 15	
	Ap2	15 - 26	slight
3	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
4	Ap1	0 - 15	
	Ap2	15 - 32	slight
5	Ap1	0 - 15	
	Ap2	15 - 30	slight
6	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
7	Ap1	0 - 15	
	Ap2	15 - 31	slight to moderate

Site #2: Lanoue

Brookston Series
Orthic Humic Gleysol
Till
Unlevelled land
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 13	Very dark grayish brown (10YR 3/2m); clay loam; granular; friable; 13 to 15 cm thick; many fine random discontinuous planar voids; many fine random discontinuous tubular voids.
Ap2	13 - 24	Dark grayish brown (10YR 4/2m); clay loam; moderate to strong medium subangular blocky; 11 to 13 cm thick; many fine discontinuous planar voids; many medium random continuous tubular voids.
Bg	24 - 60	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; moderate to strong medium subangular blocky; 32 to 35 cm thick; many fine discontinuous planar voids; common medium random continuous tubular voids.
BCg	60-100	Gray (5Y 5/1m); mottled (10YR 5/6m); clay loam; weak medium subangular blocky; firm; 35+ cm thick.

Comments

Slight to moderate compaction in Ap2 horizon.

Table 29. Soil site inspection summary, unlevelled field, Lanoue.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
8	Ap1	0 - 15	
	Ap2	15 - 28	slight
9	Ap1	0 - 15	
	Ap2	15 - 27	slight to moderate
10	Ap1	0 - 15	
	Ap2	15 - 26	slight to moderate
11	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
12	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
13	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
14	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate

Site #3: Barrette

Brookston Series
Orthic Humic Gleysol
Till
Unlevelled land
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 15	Dark grayish brown (10YR 4/2m); clay loam; granular; friable; 15 cm thick; many medium random discontinuous planar voids; many medium random continuous tubular voids.
Ap2	15 - 32	Dark grayish brown (10YR 4/2m); clay loam ; moderate medium angular blocky; firm; 10 to 17 cm thick; common fine random discontinuous planar voids; common medium random continuous tubular voids.
Bg	32 - 70	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; moderate to strong medium subangular blocky; firm; 35 to 50 cm thick; many fine random discontinuous planar voids; many very fine random discontinuous tubular voids.
BCg	70-100	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; weak medium subangular blocky; firm; 20 to 40 cm thick; Ck below.

Comments

Slight to moderate compaction in Ap2 horizon.

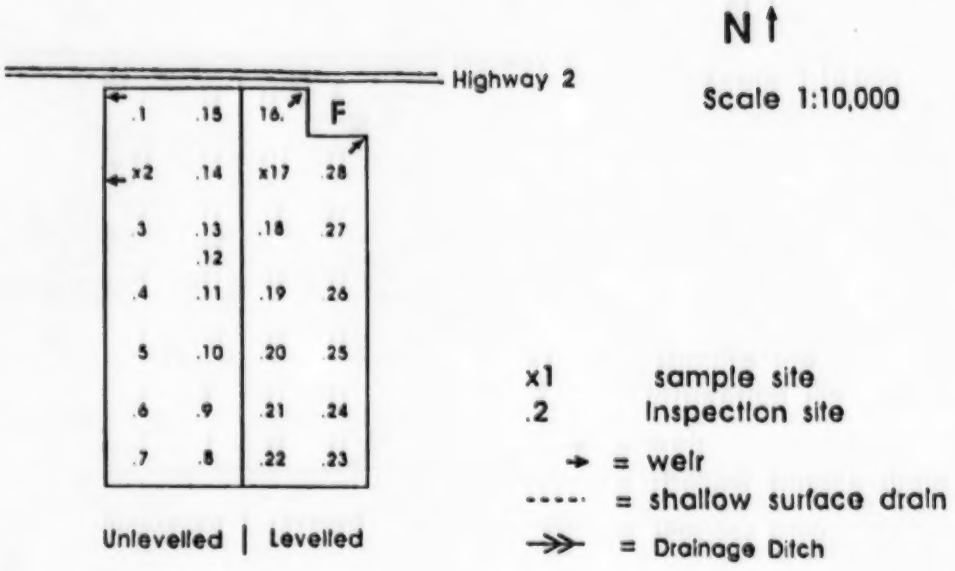

Figure 81. Field Layout and Soil Investigation Sites, Barrette.

Table 30. Soil site inspection summary, unlevelled field, Barrette.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
1	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
2	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
3	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
4	Ap1	0 - 15	
	Ap2	15 - 27	slight to moderate
5	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
6	Ap1	0 - 15	
	Ap2	15 - 24	slight to moderate
7	Ap1	0 - 15	
	Ap2	15 - 30	moderate (headland)
8	Ap1	0 - 15	
	Ap2	15 - 26	moderate (headland)
9	Ap1	0 - 15	
	Ap2	15 - 25	moderate
10	Ap1	0 - 15	
	Ap2	15 - 27	slight to moderate
11	Ap1	0 - 15	
	Ap2	15 - 27	slight to moderate
12	Ap1	0 - 15	
	Ap2	15 - 27	slight to moderate
13	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
14	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
15	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate

Site #3: Barrette

Brookston Series
Orthic Humic Gleysol
Till
Levelled land, in 1984
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 15	Dark grayish brown (10YR 4/2m); clay loam; granular; friable; 15 cm thick; many fine random discontinuous planar voids; many medium random continuous tubular voids.
Ap2	15 - 28	Dark grayish brown (10YR 4/2m); clay loam ; strong medium subangular blocky; firm; 10 to 15 cm thick; common fine random discontinuous planar voids; common medium random continuous tubular voids.
Bg	28 - 65	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; moderate medium subangular blocky; 27 to 45 cm thick; many fine random discontinuous planar voids; many very fine random discontinuous planar voids.
BCg	65-100	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; weak subangular blocky; firm; 25 to 40 cm thick; Ck below.

Comments

Field is generally slightly to moderately compacted although some sites were moderately compacted.

Table 31. Soil site inspection summary, levelled field, Barrette.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
16	Ap1	0 - 15	
	Ap2	15 - 30	slight
17	Ap1	0 - 10	
	Ap2	10 - 22	slight
18	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
19	Ap1	0 - 15	
	Ap2	15 - 23	slight to moderate
20	Ap1	0 - 15	
	Ap2	15 - 23	slight to moderate
21	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
22	Ap1	0 - 15	
	Ap2	15 - 23	slight to moderate
23	Ap1	0 - 15	
	Ap2	15 - 26	moderate (headland)
24	Ap1	0 - 15	
	Ap2	15 - 30	moderate to severe
25	Ap1	0 - 15	
	Ap2	15 - 25	moderate
26	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
27	Ap1	0 - 15	
	Ap2	15 - 33	moderate (at 15 to 35 cm)
28	Ap1	0 - 15	
	Ap2	15 - 30	moderate

Site #4: Doyle

Brookston Series
Orthic Humic Gleysol
Lacustrine
Levelled land, in 1986
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 15	Dark grayish brown (10YR 4/2m); clay loam; granular; friable; 15 to 20 cm thick; many medium random discontinuous planar voids; many medium random discontinuous tubular voids.
Ap2	15 - 30	Dark grayish brown (10YR 4/2m); clay loam; moderate coarse angular blocky; firm; 15 to 20 cm thick; common fine random discontinuous planar voids; few medium random continuous tubular voids.
Bg	30 - 65	Grayish brown (10YR 5/2m), mottled (10YR 5/6m); clay loam to clay; subangular blocky; firm; 25 to 40 cm thick; many fine random discontinuous planar voids; common very fine random discontinuous tubular voids.
BCg	65-100	Gray (10YR 5/1m); mottled (10YR 4/4m); clay loam to clay; weak subangular blocky; firm.
Ckg	100+	Gray (10YR 5/1m); mottled (10YR 5/6m); clay loam; massive; firm.

Comments

Moderate compaction at 15 to 35 cm. In one of 16 sites investigated the Ap2 was absent because the Ap1 was graded off. Otherwise, there were no apparent effects of levelling on the soil profile features.

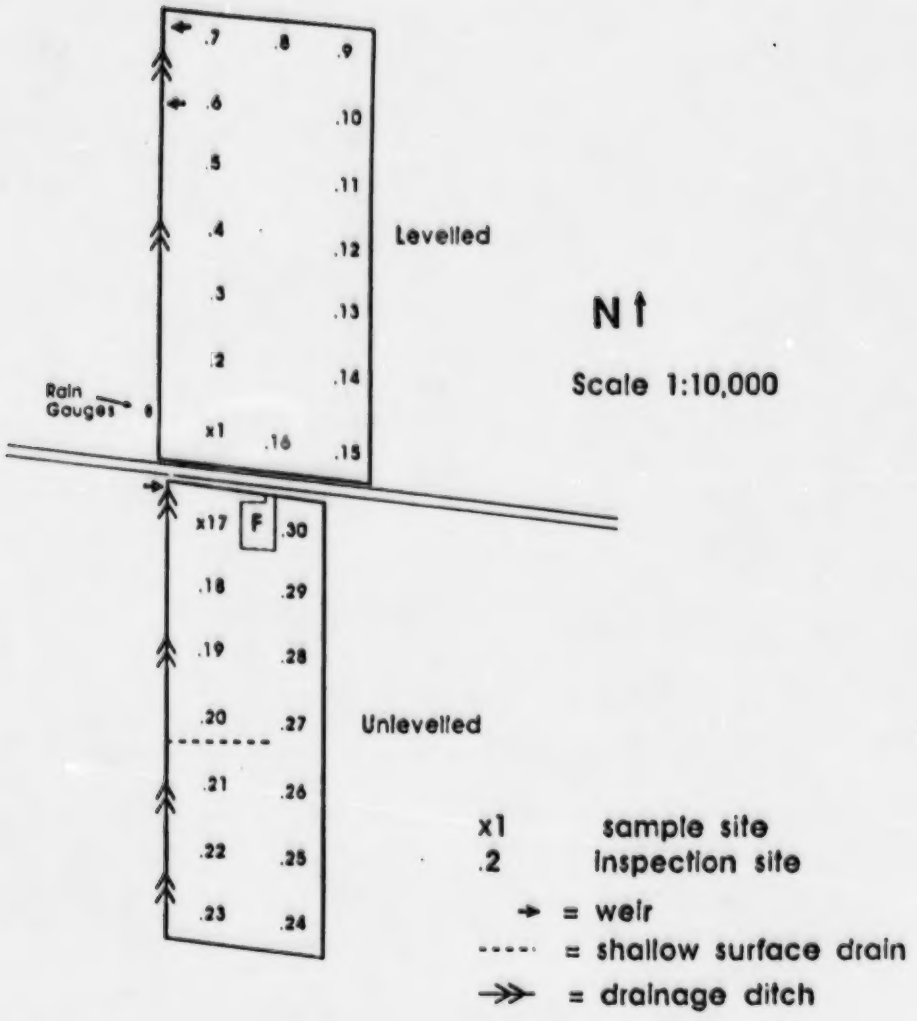

Figure 82. Field Layout and Soil Investigation Sites, Doyle.

Table 32. Soil site inspection summary, levelled field, Doyle.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
1	Ap1	0 - 15	
	Ap2	15 - 28	moderate
2	Ap1	0 - 15	
	Ap2	15 - 34	moderate
3	Ap1	0 - 15	
	Ap2	15 - 35	moderate
4	Ap1	0 - 15	
	Ap2	15 - 32	slight to moderate
5	Ap1	0 - 20	
	Ap2	20 - 34	moderate
6	Ap1	0 - 15	
	Ap2	15 - 30	moderate compaction at 15 to 35 cm
7	Ap	0 - 15	
	Bg1	15 - 21	moderate
8	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
9	Ap1	0 - 15	
	Ap2	15 - 30	moderate to severe
10	Ap1	0 - 15	
	Ap2	15 - 22	moderate compaction at 15 to 28 cm
11	Ap1	0 - 15	
	Ap2	15 - 30	moderate
12	Ap1	0 - 15	
	Ap2	15 - 30	moderate
13	Ap1	0 - 15	
	Ap2	15 - 30	moderate
14	Ap1	0 - 15	
	Ap2	15 - 30	moderate
15	Ap1	0 - 15	
	Ap2	15 - 32	moderate to severe
16	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate

Site #4: Doyle

Brookston Series
Orthic Humic Gleysol
Lacustrine
Unlevelled land
Subsurface drainage installed

HORIZON	DEPTH (cm)	DESCRIPTION
Ap1	0 - 10	Dark brown (10YR 3/3m); clay loam; granular; friable; 10 to 15 cm thick; many fine random discontinuous planar voids; many fine random discontinuous tubular voids.
Ap2	10 - 28	Dark brown (10YR 4/3m); clay loam; strong, coarse, subangular blocky; firm; 10 to 20 cm thick; common fine random discontinuous planar voids; common medium random continuous tubular voids mottled (10YR 5/6).
Bg	28 - 65	Grayish brown (10YR 5/2m); clay loam; subangular blocky; firm; 35 to 45 cm thick; many fine random discontinuous planar voids; common fine random continuous tubular voids.
BCg	65-100	Gray (10YR 5/1m); mottled (10YR 4/4m); weak subangular blocky; firm; 30 to 40 cm thick.
Ckg	100+	Gray (10YR 5/1m); mottled (10YR 4/4m); clay loam; massive; firm.

Comments

Moderate compaction at 15 to 30 cm. Soil is uniform throughout. There are shallow surface drains to enhance runoff.

Table 33. Soil site inspection summary, unlevelled field, Doyle.

Site	Upper Horizons	Depth (cm)	Degree of Compaction
17	Ap1	0 - 10	
	Ap2	10 - 25	moderate compaction at 10 to 28 cm
18	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
19	Ap1	0 - 15	
	Ap2	15 - 30	slight to moderate
20	Ap1	0 - 15	
	Ap2	15 - 30	moderate
21	Ap1	0 - 15	
	Ap2	15 - 28	slight to moderate
22	Ap1	0 - 15	
	Ap2	15 - 26	slight to moderate
23	Ap1	0 - 15	
	Ap2	15 - 28	moderate
24	Ap1	0 - 15	
	Ap2	15 - 20	moderate
25	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
26	Ap1	0 - 15	
	Ap2	15 - 28	moderate
27	Ap1	0 - 15	
	Ap2	15 - 28	moderate
28	Ap1	0 - 15	
	Ap2	15 - 25	slight to moderate
29	Ap1	0 - 15	
	Ap2	15 - 28	moderate to severe
30	Ap1	0 - 15	
	Ap2	15 - 26	moderate

Table 34. Penetrometer measurements at Site #1, fall 1988.

Unlevelled Land

Dickey-john® penetrometer (lbs/in², mean of five readings per site)

Depth (cm)	Site 14	15	16	17	18	19	Mean
0 - 8	105	100	100	120	50	60	90
8 - 16	195	185	150	180	135	160	170
16 - 24	225	220	205	310	180	260	235
24 - 32	295	280	275	350	220	355	295
32 - 40	325	350	340	380	275	380	340
40 - 48	355	395	385	400	310	400	375

Pocket penetrometer (kg/cm², mean of 5 readings per site)

Horizon	Site 14	15	16	17	18	19	Mean
Ap1 (topsoil, 0-15 cm)	0.8	0.6	0.8	1.4	1.7	1.4	1.1
Ap2 (compacted layer, 15-30 cm)	1.6	1.9	2.6	1.8	2.6	2.6	2.2
Bg (subsoil, 30-45 cm)	1.9	1.8	2.3	2.5	2.2	1.8	2.1

Levelled Land

Dickey-john® penetrometer (lbs/in², mean of 5 readings per site)

Depth (cm)	Site 35	36	37	38	39	40	Mean
0 - 8	20	50	40	20	10	0	25
8 - 16	85	135	70	70	15	15	65
16 - 24	160	145	140	150	90	55	125
24 - 32	185	185	185	185	175	135	175
32 - 40	250	255	235	230	180	160	220
40 - 48	315	320	270	320	225	240	280

Pocket penetrometer (kg/cm², mean of 5 readings per site)

Horizon	Site 35	36	37	38	39	40	Mean
Ap1 (topsoil, 0-15 cm)	1.2	1.6	1.4	1.2	1.5	1.2	1.4
Ap2 (compacted layer, 15-30 cm)	1.9	1.0	1.1	1.5	1.8	2.2	1.6
Bg (subsoil, 30-45 cm)	2.0	1.2	1.0	1.7	2.0	1.7	1.6

Table 35. Penetrometer measurements at Site #2, fall, 1988.

Dickey-john® penetrometer (lbs/in², mean of 5 readings)

Depth (cm)	Levelled Land	Unlevelled Land
0 - 8	70	0
8 - 16	165	10
16 - 24	230	190
24 - 32	255	245
32 - 40	275	270
40 - 48	305	275

Pocket penetrometer (kg/cm², mean of 5 readings)

Horizon	Levelled Land	Unlevelled Land
Ap1 (topsoil, 0-15 cm)	1.2	1.4
Ap2 (compacted layer, 15-30 cm)	2.2	2.2
Bg (subsoil, 30-45 cm)	3.0	2.4

Table 36. Penetrometer measurements at Site #3, fall, 1988.

Dickey-john® penetrometer (lbs/in^2, mean of 5 readings)

Depth (cm)	Levelled Land	Unlevelled Land
0 - 8	30	0
8 - 16	160	165
16 - 24	240	240
24 - 32	280	240
32 - 40	310	280
40 - 48	320	325

Pocket penetrometer (kg/cm^2, mean of 5 readings)

Horizon	Levelled Land	Unlevelled Land
Ap1 (topsoil, 0-15 cm)	1.1	0.9
Ap2 (compacted layer, 15-30 cm)	2.6	2.8
Bg (subsoil, 30-45 cm)	2.4	2.5

Table 37. Penetrometer measurements at Site #4, fall, 1988.

Dickey-john® penetrometer (lbs/in², mean of 5 readings)

Depth (cm)	Levelled Land	Unlevelled Land
0 - 8	0	95
8 - 16	90	160
16 - 24	225	230
24 - 32	260	260
32 - 40	320	300
40 - 48	350	360

Pocket penetrometer (kg/cm², mean of 5 readings)

Horizon	Levelled Land	Unlevelled Land
Ap1 (topsoil, 0-15 cm)	1.0	1.7
Ap2 (compacted layer, 15-30 cm)	2.6	2.5
Bg (subsoil, 30-45 cm)	2.7	3.0

Table 38. Soil textures and organic matter contents, fall 1988.

Farm	Site	Horizon	Texture	Sand	Silt	Clay	Organic Matter
				%			
Site #1							
Levelled	35	Ap	HC	12	28	60	4.5
		Bg	HC	9	26	65	1.7
		Cg	HC	10	28	62	0.0
	36	Ap	C	12	28	60	4.4
		Bg	HC	9	28	63	1.7
		Cg	C	8	34	58	0.0
	37	Ap	C	12	28	60	4.2
		Bg	HC	10	26	64	1.7
		Cg	HC	12	27	61	0.0
	38	Ap	C	11	29	60	4.0
		Bg	HC	11	27	62	1.5
		Cg	C	21	29	50	0.0
	39	Ap	C	12	28	60	4.0
		Bg	HC	9	27	64	1.7
		Cg	HC	8	27	65	0.0
	40	Ap	C	14	28	58	3.6
		Bg	HC	9	27	64	1.1
		Cg	HC	8	30	62	0.0
Unlevelled	14	Ap	C	12	29	59	4.2
		Bg	HC	10	26	64	2.4
		Cg	HC	7	31	62	0.0
	15	Ap	HC	12	28	60	4.0
		Bg	HC	11	28	61	3.9
		Cg	HC	12	26	62	0.0
	16	Ap	C	18	27	55	4.0
		Bg	C	16	26	58	1.5
	17	Ap	C	24	24	52	3.3
		Bg	HC	8	27	65	1.2
		BCg	HC	8	28	64	0.0
	18	Ap	HC	12	27	61	3.7
		Bg	HC	9	23	68	1.2
		BCg	HC	12	25	63	0.0
	19	Ap	C	20	25	55	3.3
		Bg	HC	14	26	60	1.3
		Cg	C	16	26	58	0.0
Site #2							
Levelled	15	Ap	CL	45	26	29	2.3
		Bg	C	20	39	41	0.7
		Cg	CL	26	43	31	0.0
Unlevelled	16	Ap	CL	33	35	32	3.0
		Bg	CL	33	34	33	1.5
		Cg	Cl	40	30	30	0.0

Table 38. Soil textures and organic matter contents, fall 1988 (concluded).

Farm	Site	Horizon	Texture	Sand	Silt	Clay	Organic Matter
				---------- % ----------			
Site #3							
Levelled	17	Ap	CL	29	40	31	3.5
		Bg	CL	27	37	36	0.7
		Cg	CL	22	43	35	0.0
Unlevelled	2	Ap	CL	21	41	38	3.6
		Bg	C	19	40	41	1.2
		Cg	CL	21	41	38	0.0
Site #4							
Levelled	1	Ap	SIC	18	41	41	3.7
		Bg	C	17	39	44	1.1
		Cg	SIC	14	41	45	0.0
Unlevelled	17	Ap	SIC	17	42	41	3.3
		Bg	C	17	39	44	1.7
		Cg	C	16	37	47	0.0